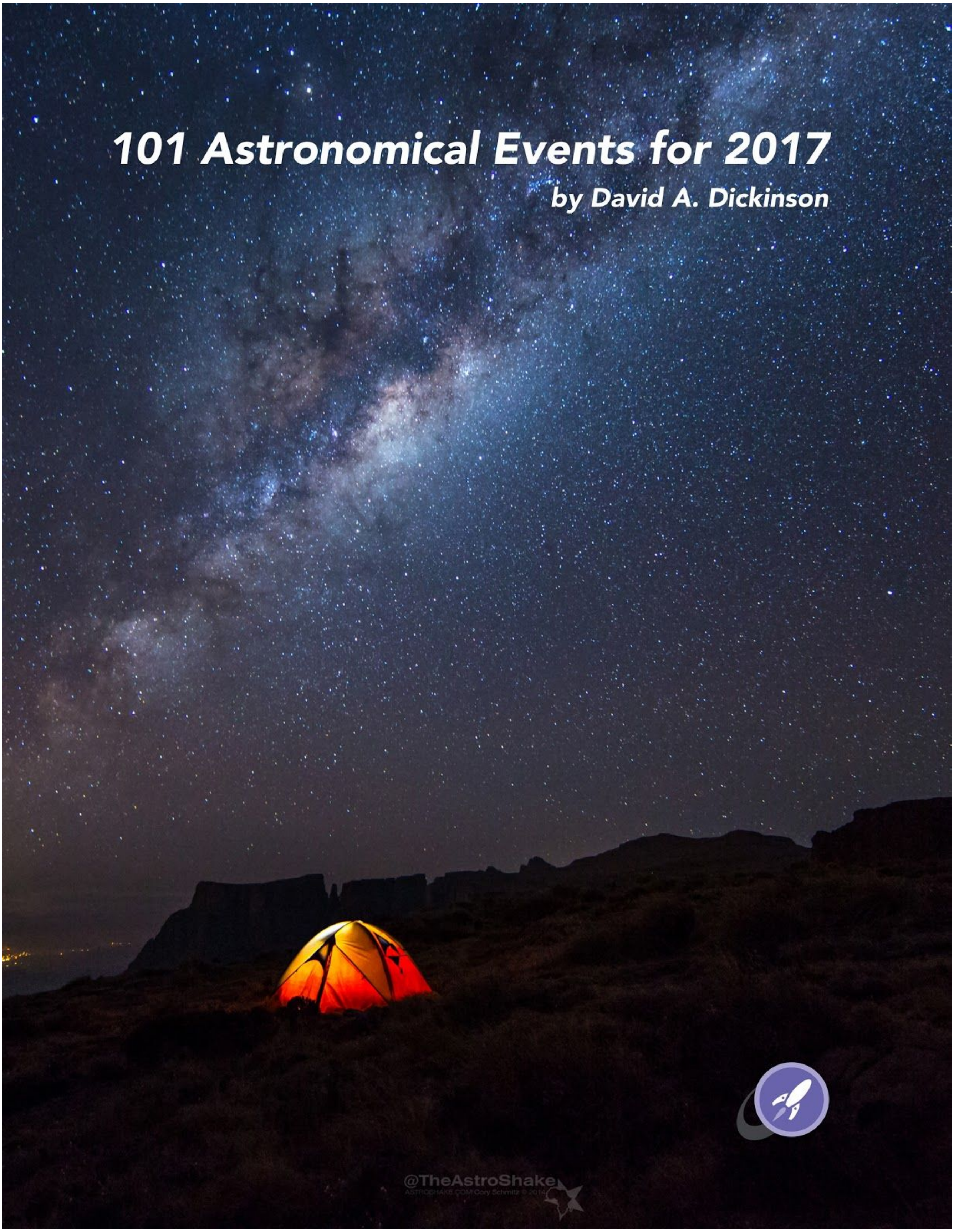
101 Astronomical Events for 2017

by David A. Dickinson



101 Astronomical Events for 2017

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Introduction

Welcome to our guide to all things astronomical in 2017. What started as a brief list of astronomical events for the coming year on our own blog way back in 2009 has now grown into the compendium you now have before you. This isn't an almanac, nor is it a laundry list of Moon phases and planetary rising and setting times, but a drilled down list of the 'best of the best' somewhere in between.

We always used to joke that this is the 'blog post that takes six months to write,' and this year, we're taking it it to the next level as a fully fleshed out guide to the top events worldwide for the coming year, interspersed with some related tales from astronomical lore and guides to the night sky. Some of these are culled from articles we wrote over the past few years for *Universe Today* and our own blog, www.astroguyz.com, and a few are new and written exclusively for this book. Our aim is to drill down planetary and lunar events to include occultations, eclipses and assorted astronomical weirdness into something very special: the very best in the night sky for the coming year worldwide. We'll give you the reasoning for the selection process and a list of resources and links to find out more.

This guide is aimed at the mid- to advanced observer of the night sky. Some previous familiarity with observational astronomy is assumed, as these range from naked eye to binocular and telescopic events. For the novice (and even a skilled observer) resources such as the free planetarium program Stellarium and others listed near the end of the book are a great compendium guides to the night sky.

This guide is also a worldwide in scope. Some events, such as planetary oppositions and lunar eclipses, for example, are visible over a wide swath or the entirety of the planet, while others such as an occultation of a star by an asteroid are visible only along a narrow (and often remote) selected path. Each entry looks at every event in brief detail, along with the visibility circumstances. There's a sky over everyone's head, and it's our goal to take observational astronomy and our love affair with the skies to a worldwide audience.

Finally, we want to hear from, you, the reader. This yearly guide if very much a running work in progress, and we've worked to include suggestions and criticisms from past years to make this guide to the top events for the coming year something special. Did we miss your favorite must see event? Is there something coming up in the coming years we should know about? Drop us a line at *Universe Today*, www.astroguyz.com or @astroguyz on Twitter and let us know.

We been observing the night sky for going on half a century now, and every night, we still challenge ourselves to see something new. We're also a great fan of international independent travel, and we always try to seek out astronomy clubs, observatories and lovers of the night sky wherever we roam on this fair planet. This also means that we might find ourselves observing the sky on any given night with anything from binoculars, to a telescope,

to nothing more than a simple pair of 'Mark-1 eyeballs.' In some ways, we enjoy this the most, as you are simply approaching the sky as our ancestors did, as they tried to organize and make sense of their strange little corner of a big universe. The cosmos makes us think big, and although there are events we'll never see thousands or millions of years past and future, we can eagerly anticipate another amazing year ahead in astronomy for 2017.

2017 Events- An Explainer

The rules: here's a brief rundown of our reasoning for selecting the top 101 events for 2017, and what it takes to make the cut:

Asteroid occultations: Every year, hundreds of asteroids occult (pass in front of) distant background stars. These can be dramatic events as the star actually winks out for a brief few seconds and then reappears again. To accurately predict the path of an asteroid occultation, we need to know not only the precise position of the star to a high degree, but the refined orbit of the asteroid as well. Before 1970 the computational power and accurate star positions simply didn't exist to predict asteroid occultations. For this list, we drew on Steve Preston's best picks for 2017, and listed predictions worldwide with a 99% probability of a hit involving a star shining at +8th magnitude or brighter.

Close conjunctions: A close paring of a bright star with a planet or two bright planets is an unforgettable sight. To make the cut for this list, a pass must be closer than one degree (with width of two Full Moons), and involve one (or two) of the five naked eye planets (Mercury, Venus, Mars, Jupiter and Saturn) and/or the one of four +1st magnitude stars (Antares, Spica, Aldebaran or Regulus) near the ecliptic.

Comets: A tricky one, as new comets come and go without warning. For this list, we looked at known comets projected to be brighter than magnitude +10 (binocular visibility from dark skies) for the coming year. Keep in mind, this is as of late November 2016... the next great comet could show up at any time, and we generally have a few extra short notice binocular comets on any given year. A good rundown is Seiichi Yoshida's *Weekly Information About Bright Comets*.

Double shadow transits of Jupiter's moons: Jupiter's large three inner moons (Io, Europa and Ganymede) are locked in a 4:2:1 resonance, meaning that they can, on occasion, cast shadows back on to the cloud tops of Jupiter at the same time. These seasons for double transits happen roughly about six months apart. The only double shadow events we excluded are those that occur within 7.5 degrees from the Sun and are unobservable. For this project, we used Starry Night Education planetarium software to tease out these events.

Eclipses: Two to three times a year, the ascending and descending nodes of the Moon's orbit match the ecliptic solar longitude, and a pair (or very rarely, a triplet) of solar and lunar eclipses occur. Fred Espenak's NASA page of solar and lunar eclipses lists out events over a

five millennium span from 2000 BC to 3000 AD.

Meteor showers: Of the dozen recognized annual meteor showers, we selected the showers with a projected Zenithal Hourly Rate (ZHR) of 10 or greater for the coming year. The International Meteor Organization (IMO) keeps a complete list of meteor showers for the coming year.

Occultations of bright stars: In our current epoch, the Moon can occult four bright stars: Aldebaran, Spica, Antares and Regulus. We excluded events that occur closer than 7.5 degrees from the Sun.

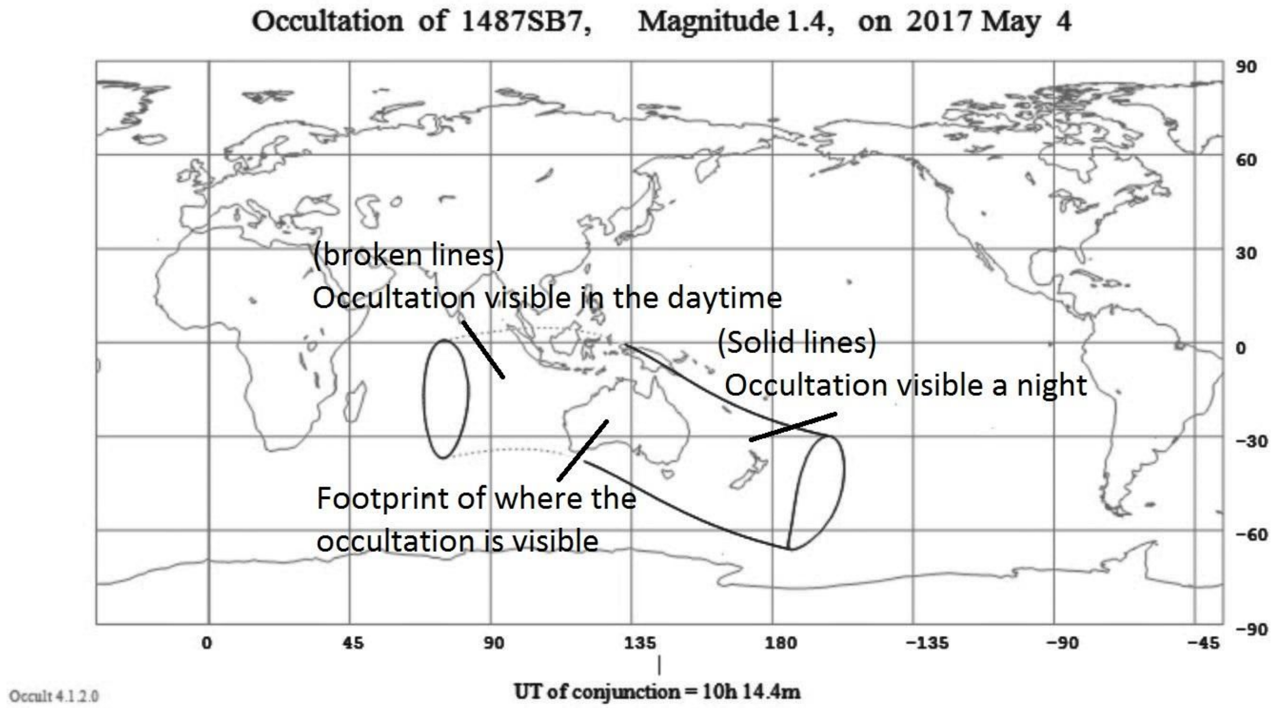
Oppositions and greatest elongations: The outer planets (Mars, Jupiter, Saturn, Uranus and Neptune) can reach 180 degrees opposite to the Sun; this is known as the middle of *opposition season*, and is the best time to view an outer planet. The inner planets of Venus and Mercury can never reach this point, but instead reach greatest elongation either to the east (dusk) or west (dawn) from the Sun.

Occultations of planets: The Moon can occult planets as well as stars on its path through the sky. For this collection, we ran simulations in Occult 4.2 and selected events involving naked eye planets greater than 7.5 degrees from the Sun.

Planets that occult stars, asteroids: Rarer still, but it does happen. In 2044, for example, the planet Venus will occult the bright star Regulus. Very occasionally, an asteroid might transit (pass in front of) a planet from our point of view, though such an event would be tough to observe visually.

Weirdness: Every year, a few unique events occur that defy the categories above. Examples in 2017 include Saturn's rings at their widest and the Sun headed towards a profound solar minimum as Cycle #25 approaches. In addition to the two equinoxes and solstices, we also included the closest perigee and most distant apogee Full Moons of the year, as well as curious cultural pseudo-events known Black and Blue Moons.

Got it? Those are the rules... now, let's run down what's up in 2017.



A example and key to occultation maps used in this guide. The time denotes the approximate conjunction time for the pair. Consult the International Occultation Timing Association webpage for a full list of ingress and egress times by location. Credit: Occult 4.1.2.

January 2017

Sunday, January 1st: The Deepening Solar Minimum

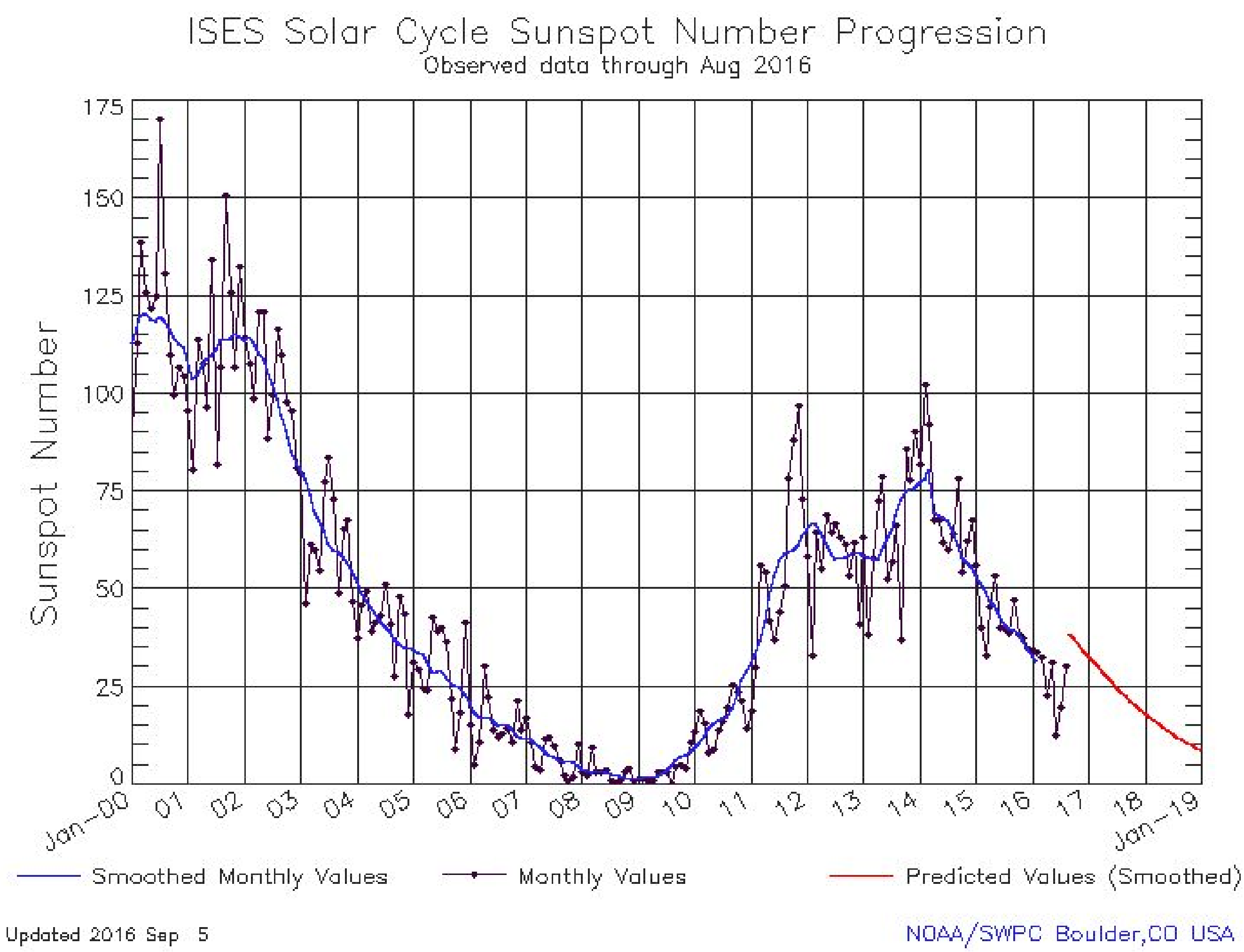
The Sun on January 31, 2016 by Paul Stewart.
https://upsidedownastronomer.wordpress.com/

Our host star the Sun goes through an 11 year cycle, during which sunspot activity goes from a maximum peak in activity, to a minimum ebb and then back again. 2017 sees solar cycle

#24 on a downward slide, past its peak in 2014 and towards an expected shallow minimum in 2020. The last minimum in 2009 was especially profound, with a total of 260 (71% of the year) spotless days on the Earthward face of the Sun, an enduring subsidence that was the longest recorded in over a century.

There's been some discussion among solar heliophysicists (those who study the physics of the Sun) that the minimum marking the end of solar cycle #24 might be deeper still, and that solar cycle #25 will fail to appear all together. Does the Sun have longer, as of yet undiscovered periods of activity?

This also means that we can expect a lower number of sunspots gracing the disk of Sol during the two solar eclipses of 2017 on February 26th and August 21st, and a lower level of auroral activity visible from high latitudes. But remember: a large sunspot group can always appear... even during the depth of a solar minimum.

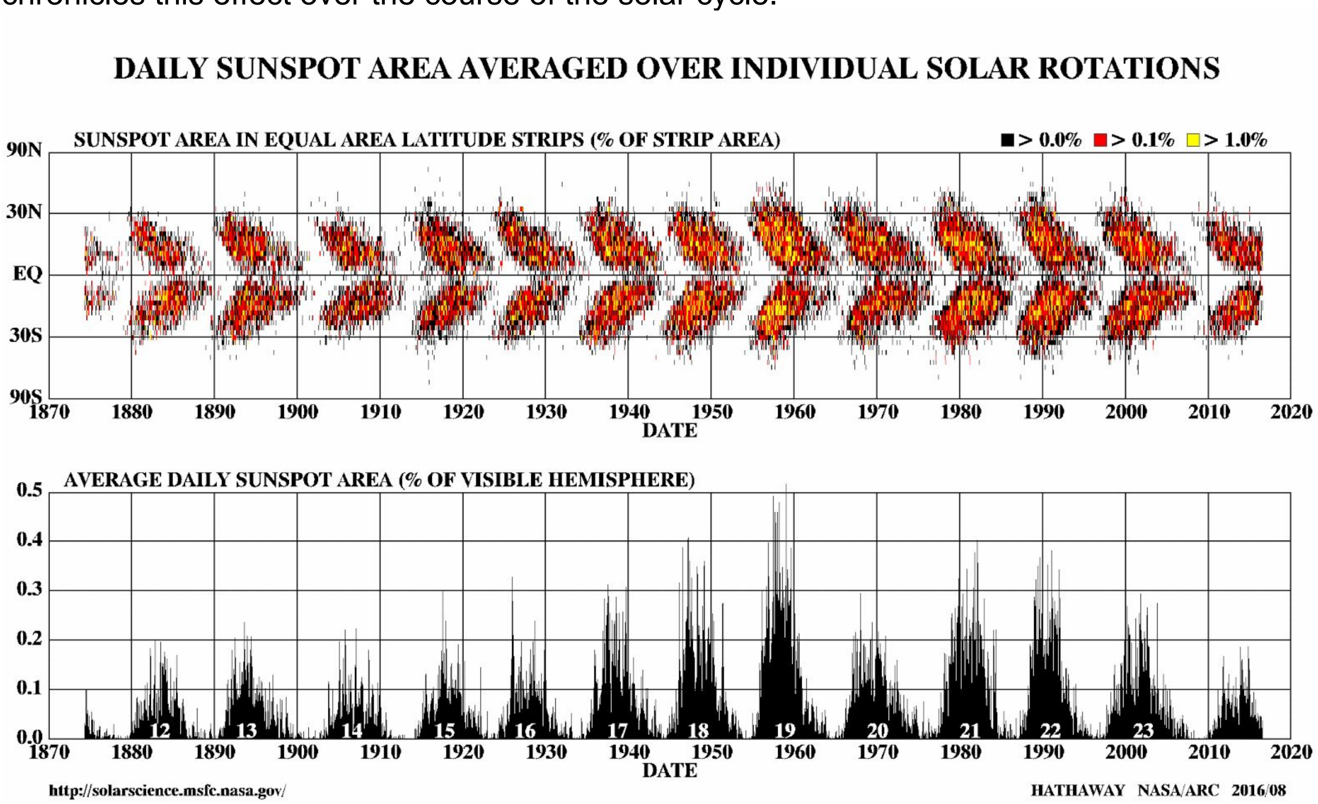


Solar cycle #24 in to #24: observed sunspot numbers versus predictions through the remainder of the decade. Credit: NOAA/SWPC.

One 2013 study from the University of Michigan in Ann Arbor suggests that the current standard calculation of the daily sunspot number might be a relatively poor indicator of solar health, and that perhaps the status and orientation of the Heliospheric Current Sheet might be a better method for recording just what the Sun is up to.

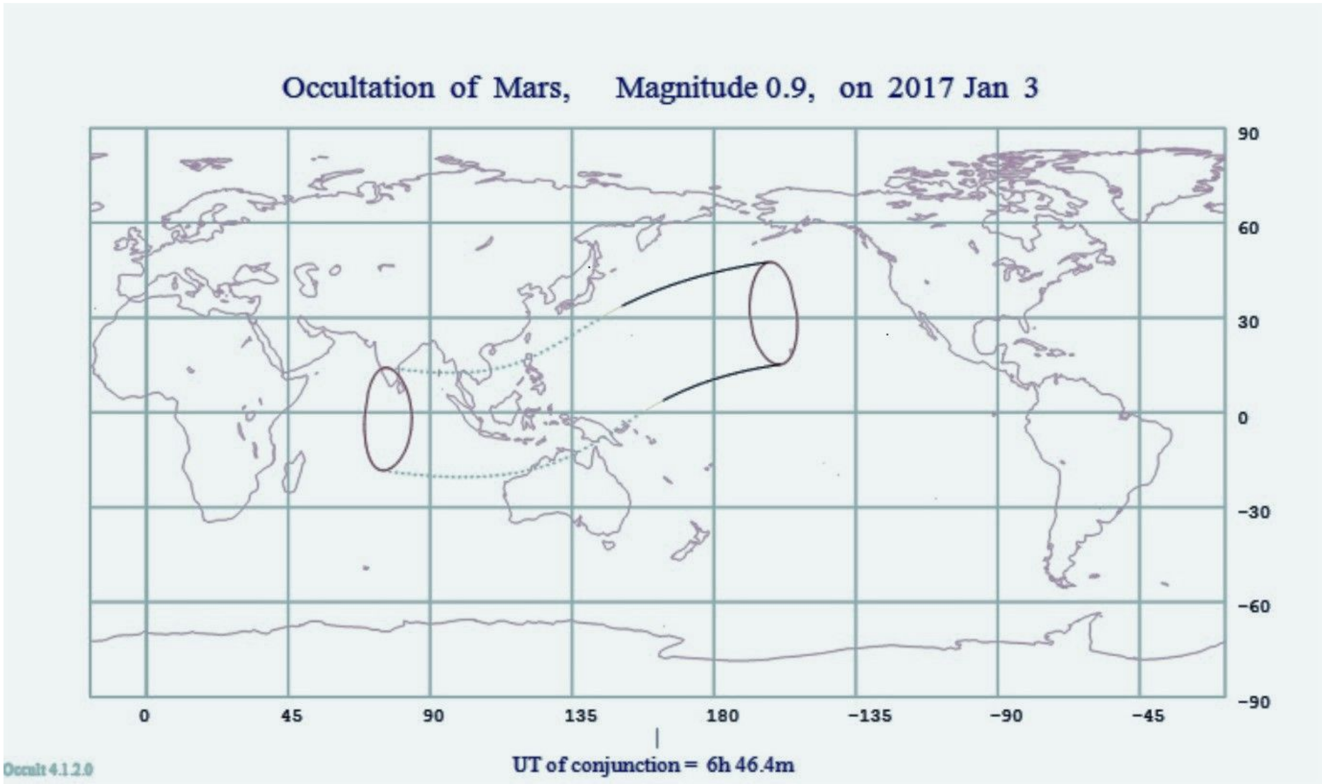
The Sun reverses its polarity during the start of each solar cycle. Tracked since 1755 with the start of Solar Cycle #1, a hallmark of the beginning of a new cycle is the appearance of sunspots at mid- to high solar latitudes. These tend to move down to low equatorial latitudes as the solar cycle progresses, in a fashion first determined by Spörer's Law.

The Sun spins once on its axis every 25.1 days at the equator and 34.4 days at its poles, and a diagram of sunspots over time (know as a *Spörer Chart*) reveals a butterfly diagram that chronicles this effect over the course of the solar cycle.



Sunspots vs latitude over time. Credit: NASA/MSFC Center for Solar Physics.

Tuesday January 3rd: The Moon occults Mars



The footprint for the January third event. Image credit: Occult 4.2.

The 23% illuminated waxing crescent Moon occults the 90% illuminated, +0.9 magnitude planet Mars. The Moon is 5 days past New during the event. Both are located 58 degrees east of the Sun at the time of the event. The central time of conjunction is 6:46 UT. The event occurs during the daylight hours over the central Pacific, and under darkness for the central Pacific, including Hawaii. The Moon will next occult Mars on September 18th, 2017. Mars is located 1.7 astronomical units (AU) or 247.7 million kilometers distant during the occultation. Mars will reach a grand opposition next year on July 27th, 2018 nearly as favorable as the historic 2003 pass of the Red Planet.

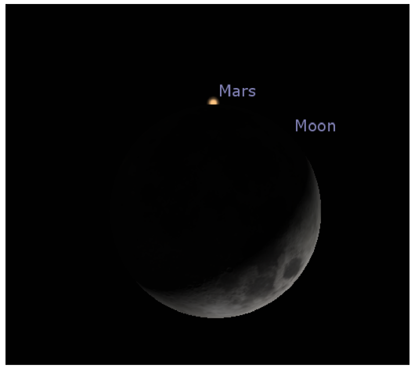
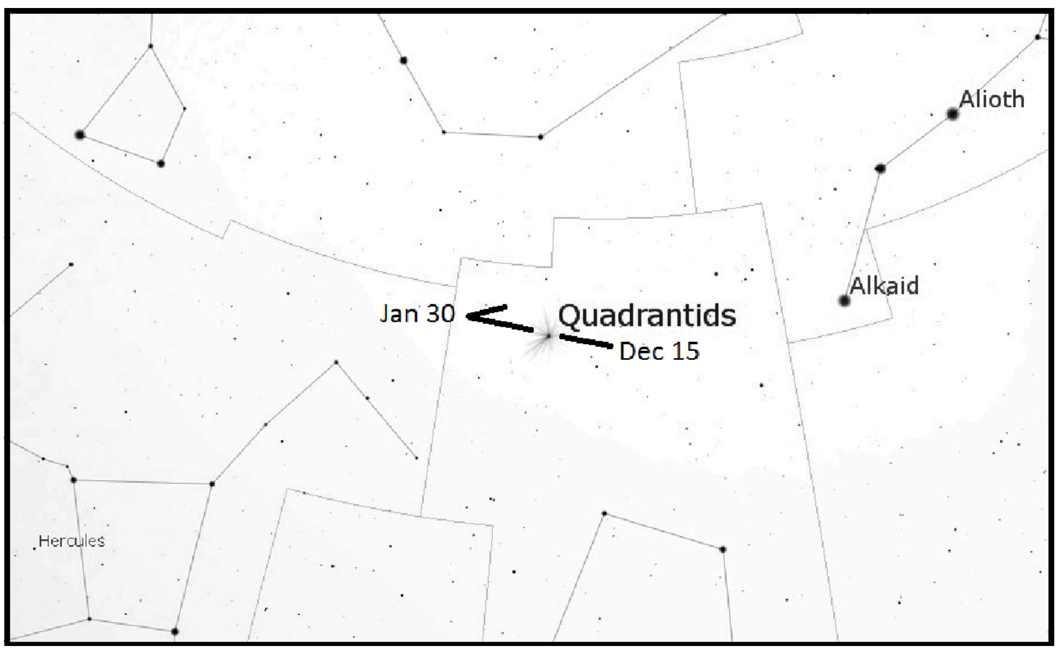


Image credit: Stellarium

Daytime occultations of planets by the Moon are tough to observe, though not impossible. Though the Moon makes a great guide to find the planet hidden against the daytime sky, its surface albedo is actually *darker* than any of the planets!

Tuesday, January 3rd: The Quadrantid Meteor Shower

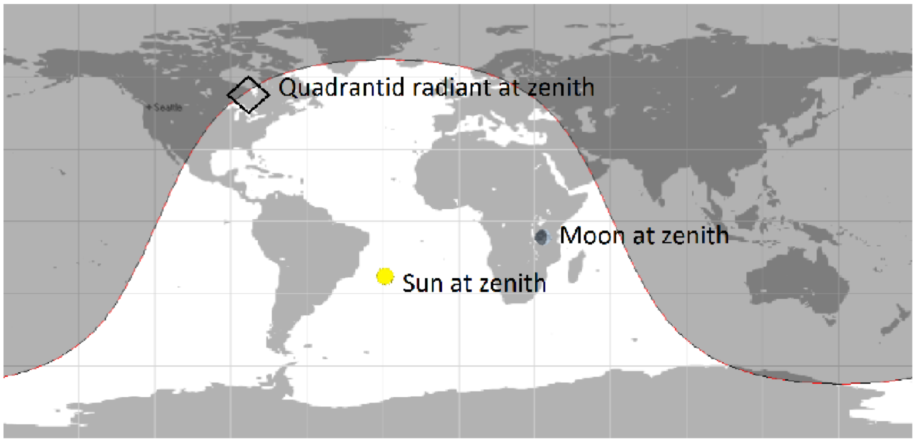


The path of the Quadrantid meteor shower radiant. (Credit: Stellarium)

The Quadrantid meteors are expected to peak on January 3rd at 14:00 UT, favoring NW North America. The shower is active for two weeks from December 28th to January 12th, and can vary with a Zenithal Hourly Rate (ZHR) of 60 to 200 meteors per hour. In 2017, the Quadrantids are expected to produce a maximum ideal ZHR of 120 meteors per hour. The radiant of the Quadrantids is located at right ascension 15 hours 28 minutes, declination +50 degrees north at the time of the peak, in the modern constellation of Boötes near the borders of Hercules and Draco.

The Moon is a 23% illuminated waxing crescent at the peak of the Quadrantids, making **2017**

a favorable year for this shower. In previous years, the Quadrantids produced a ZHR=123 (2016), but were washed out by the nearly Full Moon in 2015.



The radiant vs the Sun and Moon on January 3rd at 14:00UT. (Created using Orbitron)

The Quadrantids typically have swift peak less than 10 hours in duration. Quadrantid meteors strike the Earth at a moderate velocity of 41 kilometers per second, and produce few fireballs with an *r* = 2.1. The source of the Quadrantids is asteroid 2003 EH1. The Quadrantids take their name from the defunct constellation of *Quadrans Muralis*, or the Mural Quadrant, established by French astronomer Jérôme Lalande in 1795. The constellation has since fallen out of general use.

Wednesday, January 4th: Earth at Perihelion

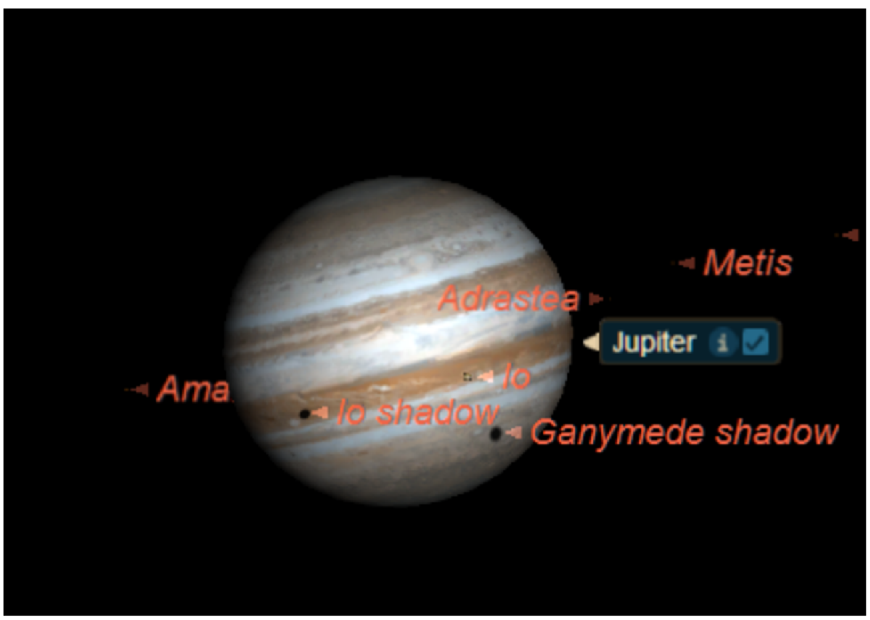
The apparent size of the Sun as seen from the Earth at perihelion vs aphelion. The red circles each indicate the size of the solar disk opposite. Photo by author.

Earth reaches perihelion, or its closest point to the Sun on January 4th at 14:18 Universal Time (UT) at 0.9833 AU (91.4 million miles, 147.1 million kilometers) distant. On this date, the Sun appears 32' 32” in diameter as seen from the Earth. In the current epoch, perihelion actually falls during northern hemisphere winter and aphelion or our farthest point from the Sun occurs during the summer, about two weeks after the June solstice.

During the 21st century, perihelion occurs anywhere from January 2nd, (which happens next in 2021) to January 5th (next 2020), and the distance for perihelion ranges from 0.9832 AU (91.398 million miles or 147.09 million kilometers) on (2020) to 0.9834 AU (91.412 million miles or 147.11 million kilometers) in 2098.

The Earth-Moon system orbits about a common barycenter located about 1,700 kilometers below the surface of the Earth, and the position of the Moon in its orbit is one of the major factors causing the Earth-Sun distance to vary slightly near perihelion and aphelion.

Wednesday, January 4th: Io/Ganymede Shadow Transit Season



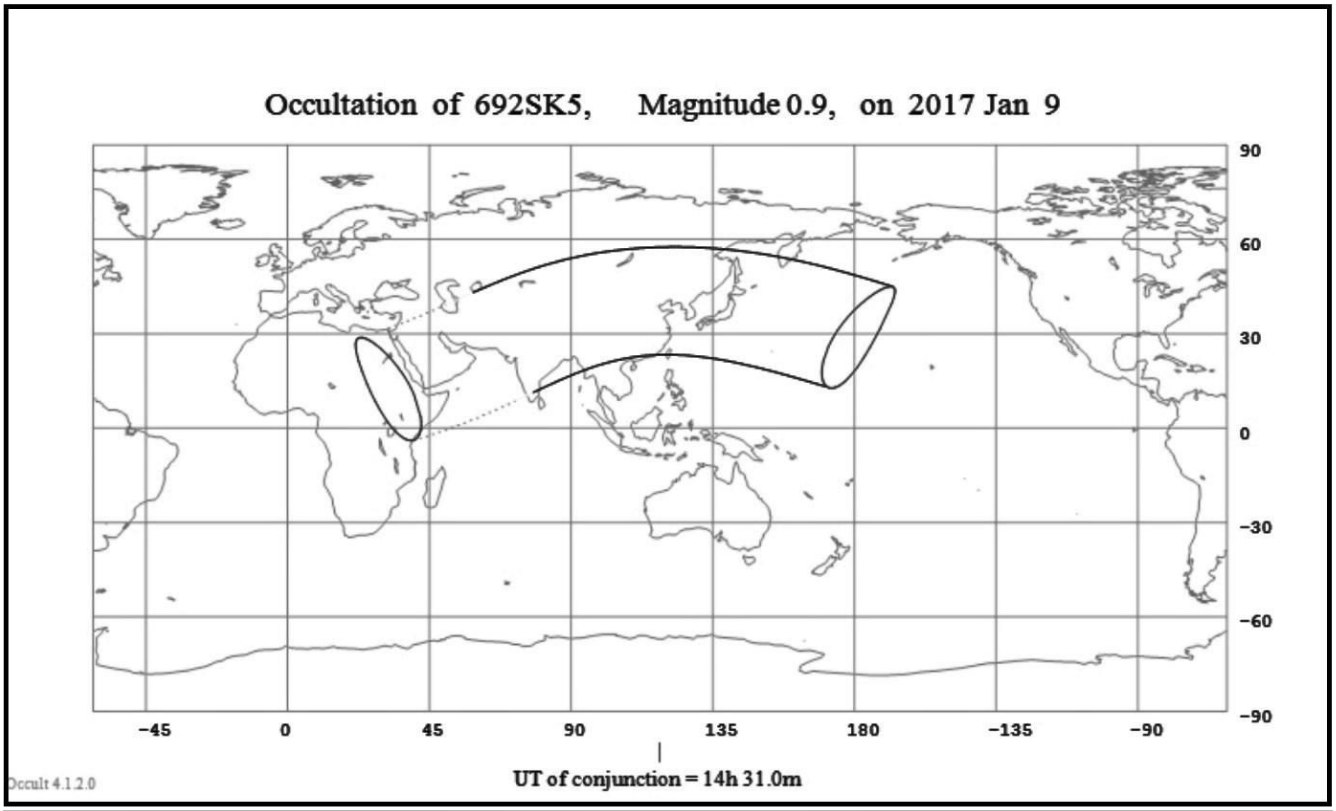
Io and Ganymede both cast shadows on Jupiter: the scene at 19:45 UT. (note: the image is inverted top to bottom for the southern hemisphere). Image credit: Starry Night.

Ganymede and Io double shadow transit season begins. This series of simultaneous transits runs from January 4th to January 11th, and includes two events. The January 11th event is especially well positioned for eastern Australia at sunrise.

Simultaneous Shadow transits of Ganymede and Io					
Date	**Solar Elongation**	**Begins**	**Ends**	**Duration**	**Region Favored**
January 4th	83 deg W	15:52 UT	17:41 UT	1 hour, 49 minutes	Central Pacific
January 11th	90 deg W	18:08 UT	20:03 UT	1 hour, 55 minutes	Australia

The last triple shadow transit of Jupiter's moons occurred on January 24th, 2015 and the next will occur on March 20th, 2032.

Monday, January 9th: The Moon occults Aldebaran



The occultation footprint for the January 9th event. Image credit Occult 4.2

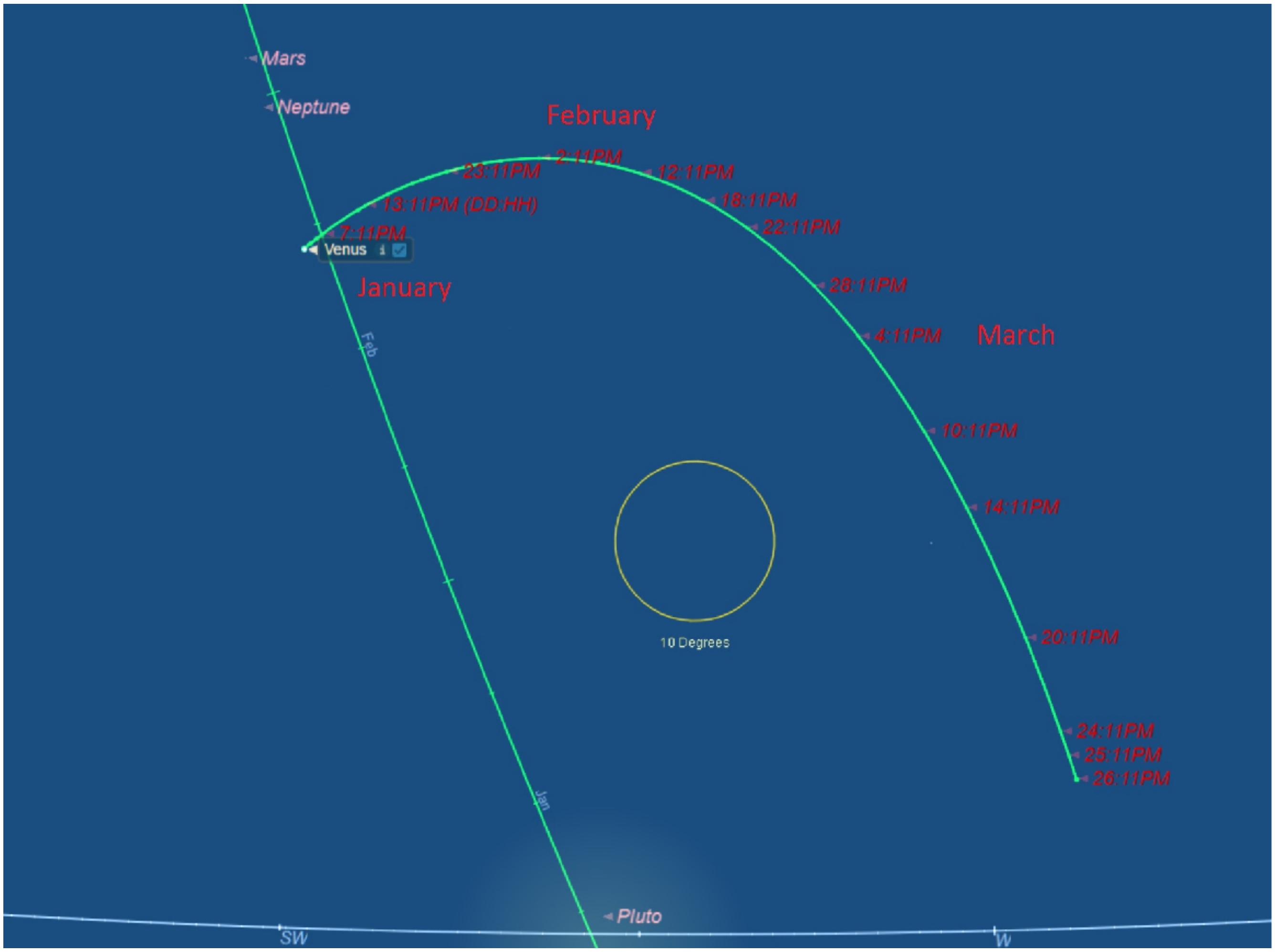
The 88% illuminated waxing gibbous Moon occults the +0.9 magnitude star Aldebaran. The Moon is 3 days from Full during the event. Both are located 140 degrees east of the Sun at the time of the event. The central time of conjunction is January 9th, 14:31 UT. The event occurs during the daylight hours over the Arabian peninsula, and under darkness for central Asia, including Japan. The Moon will next occult Aldebaran on February 5th, 2017. This is

occultation 27 in the current series of 49, running from January 29th, 2015 to September 3rd 2018. The Moon will occult Aldebaran and cross the Hyades once for every lunation in 2017.

The view on January 9th. Image credit: Stellarium.

Located 65 light years distant, Aldebaran is actually not a true member of the Hyades, which lies 153 light years away.

Thursday, January 12th: Venus Reaches Greatest Elongation

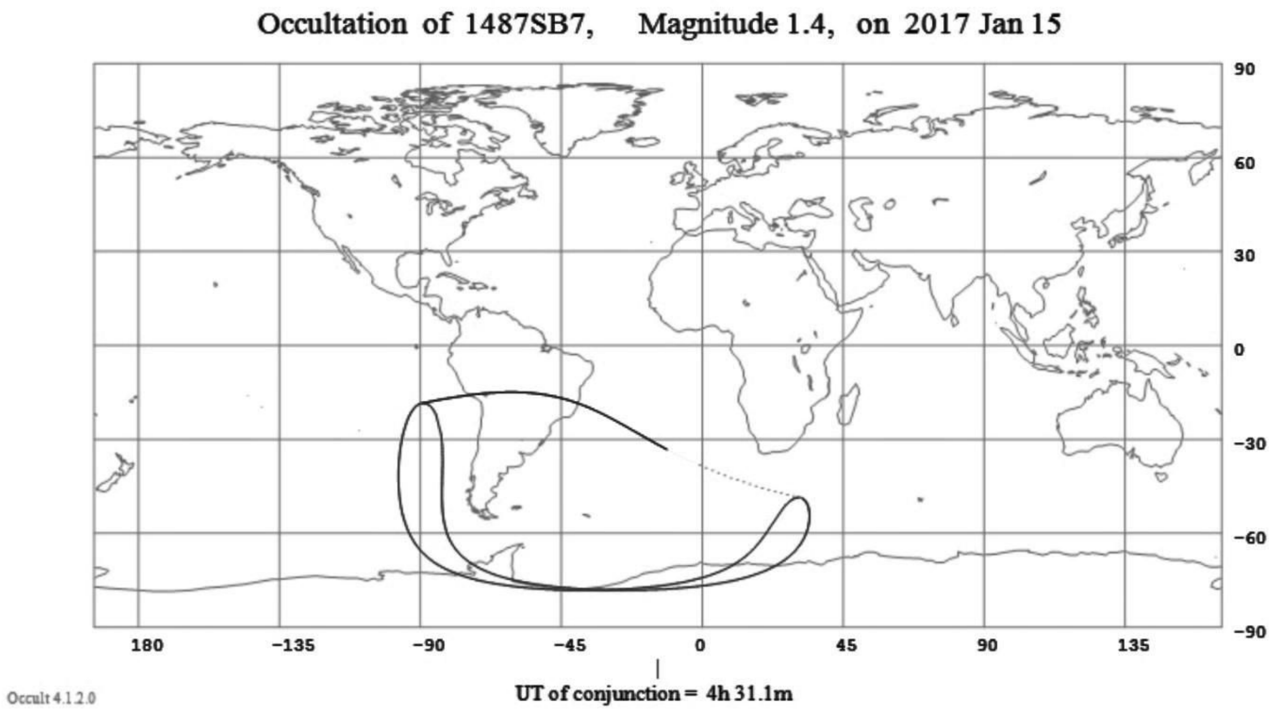


The path of Venus from January 4th to March 26th. The ecliptic angle is set for the beginning of the path. Image credit: Starry Night Education Software.

The planet Venus reaches greatest elongation, 47 degrees east of the Sun in the dusk sky. The exact hour of greatest elongation occurs on January 12th at 11:00 Universal Time (UT). Venus is 24' in apparent diameter and presents a 50% illuminated disk at greatest elongation. This is the culmination of Venus' evening apparition for 2017. Venus then begins to head back towards the Sun every evening until reaching inferior conjunction between the Sun an the Earth on March 25th, 2017. Venus reaches theoretical dichotomy (half phase) on January 14th and a maximum brilliancy of -4.6th magnitude on February 17th. Venus will next reach greatest western (dawn) elongation on June 3rd, 2017. Elongations of Venus can range from 45.4 degrees to 47.3 degrees from the Sun, and the January 11th event is the widest until 2025.

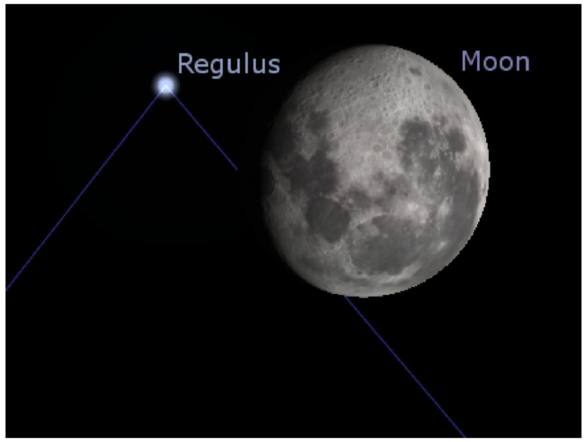
Observers have long reported ashen light on the dark limb of the Venus during crescent phases similar to Earthshine seen on the Moon, though none should exist. On the Moon, Earthshine is the result of the Earth reflecting sunlight back to the Moon; Venus has no such large nearby body to act as a celestial mirror. A psychological phenomena seen at the eyepiece, or something more? Possible proposed mechanisms over the years include air glow, aurora, lightning, or the light of perpetually shrouded Venusian cities (!).

Sunday, January 15th: The Moon occults Regulus



The occultation footprint for the January 15th event. Image credit Occult 4.2

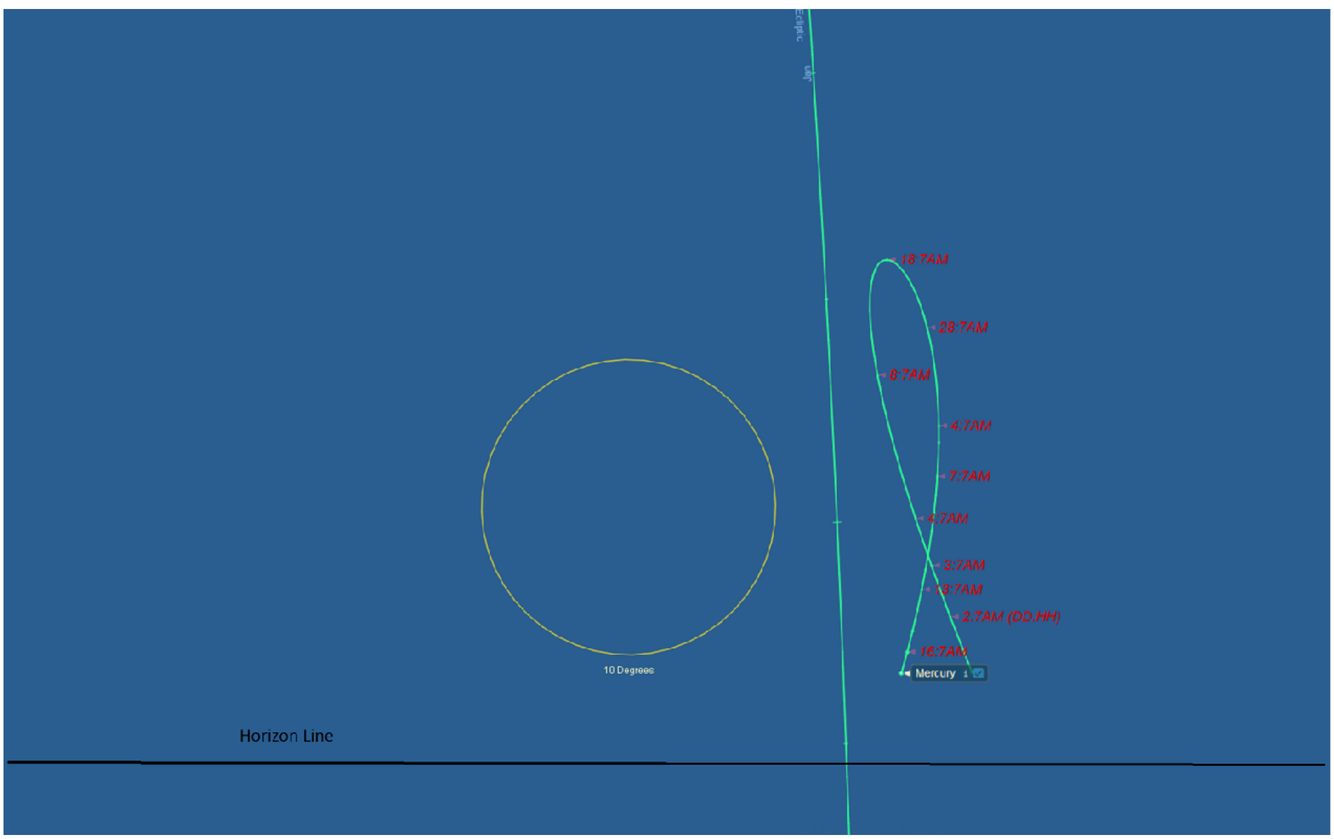
The 88% illuminated waning gibbous Moon occults the +1.4 magnitude star Regulus. The Moon is 3 days past Full during the event. Both are located 145 degrees west of the Sun at the time of the event. The central time of conjunction is 4:31 Universal Time (UT). The event occurs during the daylight hours over the southern Atlantic Ocean, and under darkness for the southern half of the South American continent, including Argentina, Chile, Uruguay and the Falkland Islands. The Moon will next occult Regulus on February 11th, 2017. This is occultation the 2nd in the current series of 19 running from December 18th, 2016 to April 24th, 2018. Located 79 light years distant, Regulus lies less than a degree from the ecliptic plane.



The view on January 15th. Image credit: Stellarium

The Moon with occult Regulus during a total lunar eclipse on February 22nd, 2445 AD.

Thursday, January 19th: Mercury at Greatest Elongation



The path of Mercury through January. Image credit Starry Night Education Software.

The planet Mercury reaches greatest elongation, 24.1 degrees west of the Sun in the dawn sky. The exact hour of greatest elongation occurs on January 19th at 13:00 Universal Time (UT). Mercury is 7” in apparent diameter and presents a 63% illuminated disk at greatest elongation. This is the first of six elongations of Mercury for 2017. Mercury then begins to head back towards the Sun every evening until reaching superior conjunction on the far side of the Sun and the Earth on March 6th. Mercury reaches half phase on January 13th, and exceeds magnitude 0 on February 24th. Mercury will next reach greatest eastern dusk elongation on April 1st. This is one of the better dawn apparitions of Mercury for observers based in the southern hemisphere.

Orbiting the Sun once every 88 days, Mercury can reach greatest elongation a maximum of seven times in one year, assuming the first elongation occurs on or earlier than January 17th (assuming a leap year). Seven elongations of the planet Mercury last happened in 2015 and will next occur again in 2018.

What's Up With Sol?

The Mystery Minimum of Solar Cycle #24 and Innovative Method to Characterize Solar Activity

Prominences on the Sun. Paul Stewart. https://upsidedownastronomer.wordpress.com/.

The Sun has provided no shortage of mysteries thus far during solar cycle #24.

Perhaps the biggest news story that the Sun has generated recently is what it *isn’t* doing. The past two solar cycles #24 and #25 were especially weak one in terms of performance, and if 2016 is any indication, cycle #25 could be missing in action all together.

The magnetic polarity flip signifying the peak of the solar maximum passed in mid-2014 with a

lower than expected level of activity, and the current solar cycle #24 got off to a late start after a profound minimum in 2009.

Sol is headed towards yet another quiet stretch, as 'spotless days' become more and more prevalent. Sol is, perhaps, headed towards another once-a-century lull... or is it?

In 2013, research out of the University of Michigan in Ann Arbor’s Department of Atmospheric, Oceanic and Space Sciences published in *The Astrophysical Journal* suggested that we’re only looking at a portion of the puzzle when it comes to solar cycle activity.

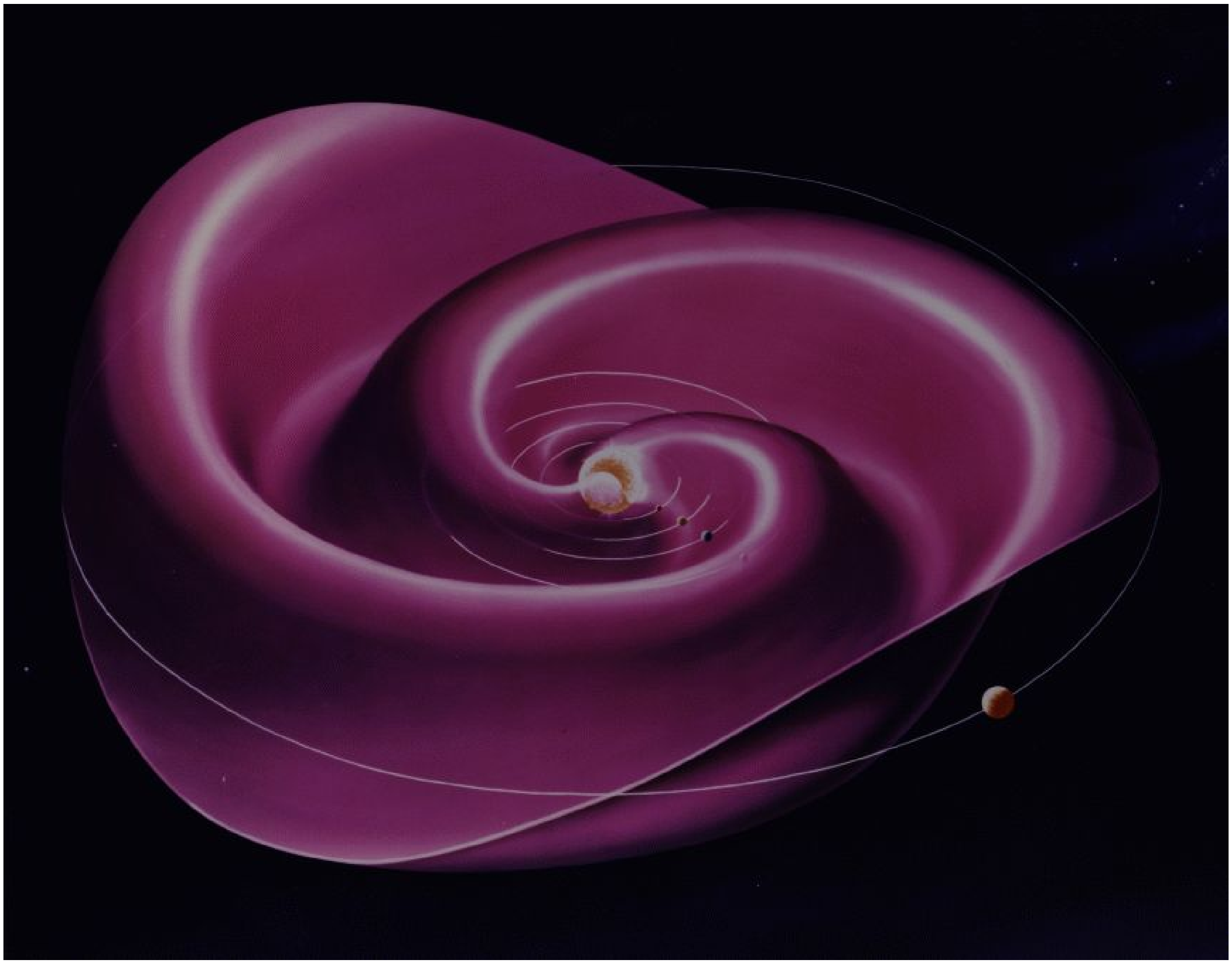
Traditional models rely on the monthly averaged sunspot number. This number correlates a statistical estimation of the number of sunspots seen on the Earthward facing side of the Sun, and has been in use since first proposed by Rudolf Wolf in 1848. That’s why you also hear the relative sunspot number referred to as the Wolf or Zürich Number.

But sunspot numbers may only tell one side of the story. In their paper titled *Two Novel Parameters to Evaluate the Global Complexity of the Sun’s Magnetic Field and Track the Solar Cycle*, researchers Liang Zhao, Enrico Landi and Sarah E. Gibson describe a fresh approach to modeling solar activity via looking at the 3-D dynamics heliospheric current sheet.

The heliospheric current sheet (or HCS) is the boundary of the Sun’s magnetic field separating the northern and southern polarity regions which extends out into the solar system. During the solar minimum, the sheet is almost flat and skirt-like; during solar maximum, it’s tilted, wavy and complex.

Two variables, known as SD & SL were used by researchers in the study to produce a measurement that can characterize the 3-D complexity of the HCS. “SD is the standard deviation of the latitudes of the HCS's position on each of the Carrington map of the solar surface, which basically tells us how far away the HCS is distributed from the equator. And SL is the integral of the slope of HCS on that map, which can tell us how wavy the HCS is on each of the map.” Liang Zhao told *Universe Today*.

Ground and space-based observations of the Sun’s magnetic field exploit a phenomenon known as the *Zeeman Effect*, which was first demonstrated during solar observations conducted by George Ellery Hale using his newly invented spectrohelioscope in 1908. For the recent study, researchers used data to characterize the HCS available online from the Wilcox Solar Observatory.



A graphic overlay of the wavy Heliospheric Current Sheet over the inner solar system. Image credit: NASA.

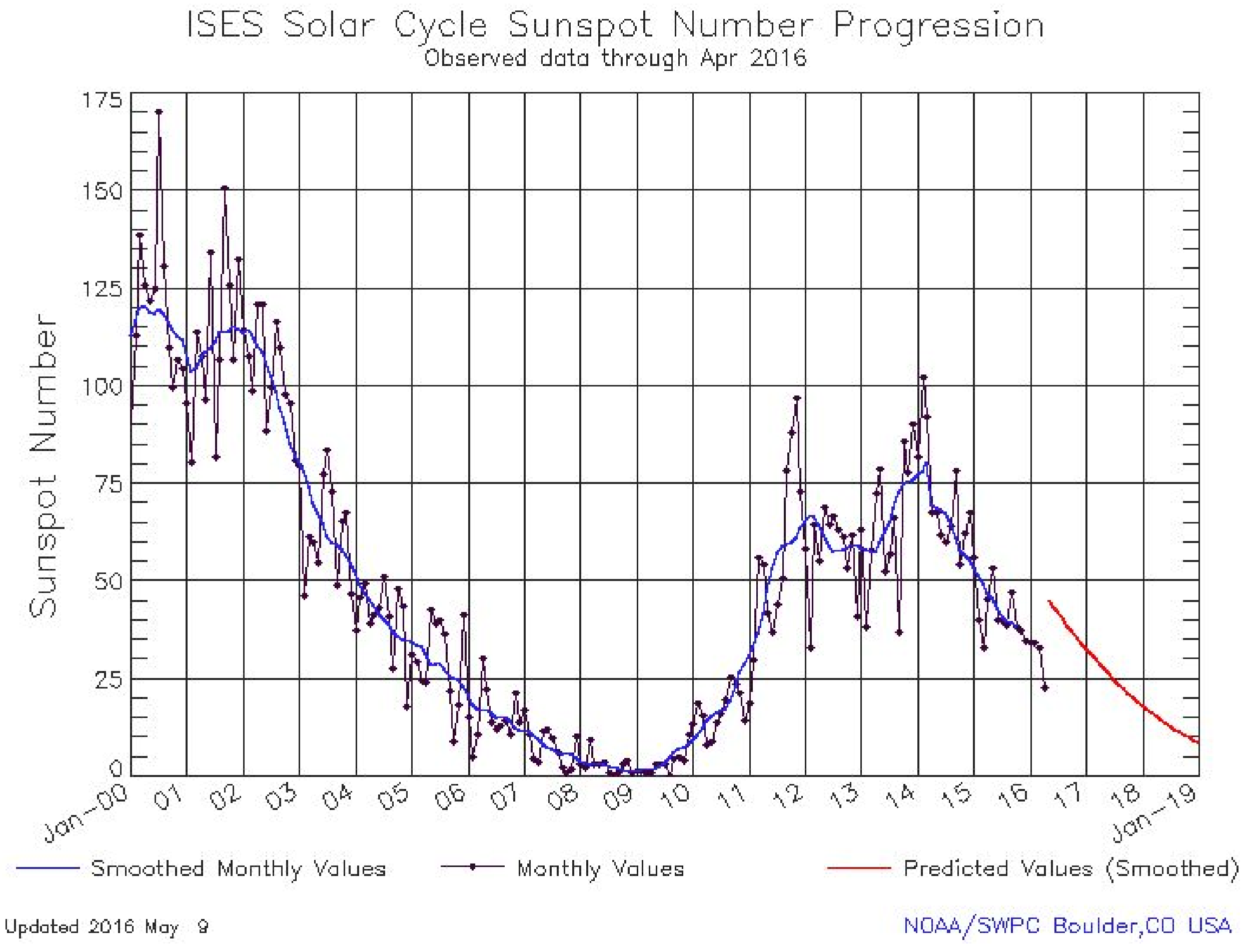
Comparing the HCS value against previous sunspot cycles yields some intriguing results. In particular, comparing the SD and SL values with the monthly sunspot number provides a "good fit" for the previous three solar cycles — right up until cycle #24.

"Looking at the HCS, we can see that the Sun began to act strange as early as 2003," Zhao said. This current cycle as characterized by the monthly sunspot number started a year late, but in terms of HCS values, the maximum of cycle #24 occurred right on time, with a first peak in late 2011.

"Scientists believe there will be two peaks in the sunspot number in this solar maximum as in the previous maximum (in ~2000 and ~2002), since the Sun's magnetic fields in north and south hemispheres look asymmetric and north evolves faster than the south recently. But so far as I can see, the highest value of monthly-averaged sunspot number in this cycle 24 is still the one in the November 2011. So we can say the first peak of cycle 24 could be in November of 2011, since it is the highest monthly sunspot number so far in this cycle. If there

is a second peak, we will see it sooner or later,” Zhao continued.

(Update: two peaks did indeed occur during solar cycle #24, in late 2011 and in early 2014).



Solar cycle #23 headed into the peak of cycle #24 in 2014. Image credit: NASA/SWPC.

The paper also notes that although cycle 24 is especially weak when compared to recent cycles, it still has a standard range of activity when compared with solar cycles over the past 260 years.

The HCS value characterizes the Sun over one complete Carrington rotation of 27 days. This is an averaged value for the rotation of the Sun, as the poles rotate slower than the equatorial regions.

The 22 year span of time that it takes for the poles to reverse back to the same polarity again is equal to two 11 year solar cycles. The Sun’s magnetic field has been exceptionally asymmetric during the current cycle, and the Sun finished its current north-pole-first field reversal in late 2014.

“This is an exciting time to study the magnetic field of the Sun, as we may actually be witnessing an (example of) a normalized cycle for the past about 300 years,” Zhao said. This sort of asymmetry during an imminent pole reversal was first recorded during solar cycle 19, which spanned 1954-1964.

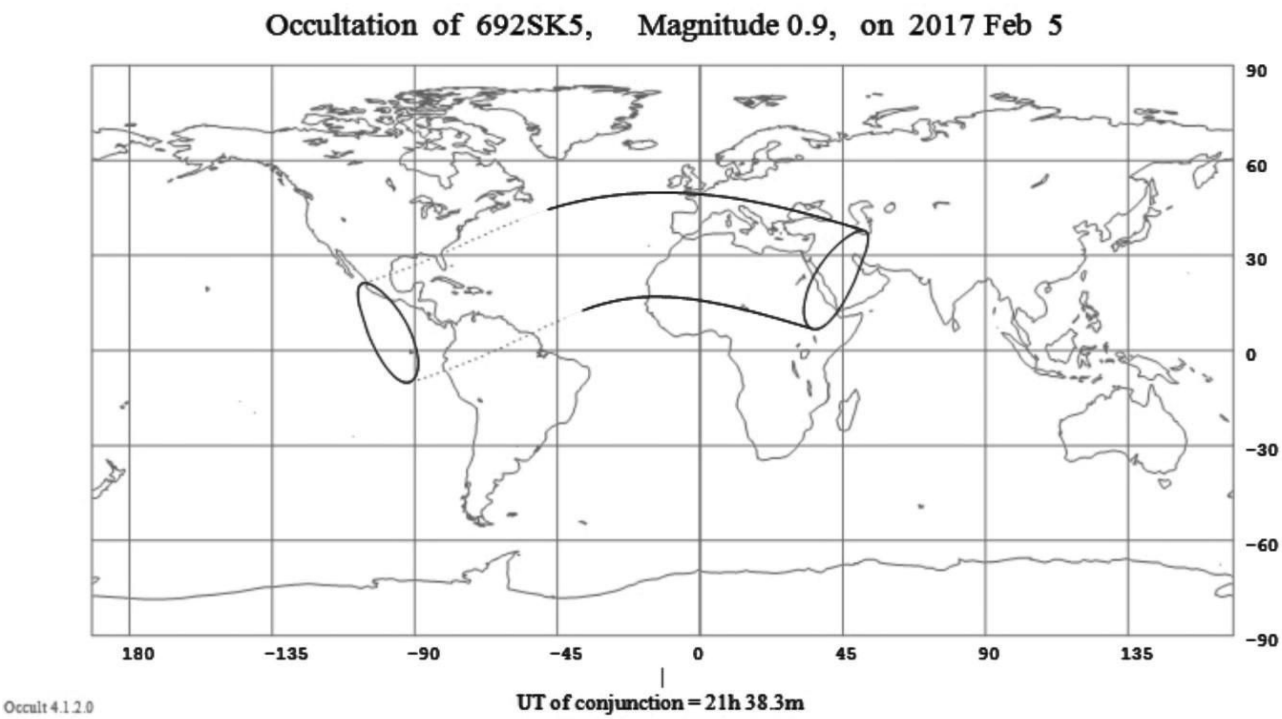
Solar cycles are numbered starting from observations which began in 1749, just four decades after the end of the 70-year Maunder Minimum.

Today, an armada of space and ground based observatories scrutinize our host star like never before. The SOlar Heliospheric Observatory (SOHO) has already followed the Sun through the equivalent of one complete solar cycle — and was joined in space by STEREO A & B, JAXA’s Hinode, ESA’s Proba-2 and NASA’s Solar Dynamics Observatory. NASA’s Interface Region Imaging Spectrograph (IRIS) is also open for business.

Will there be a second peak following the magnetic polarity reversal of the Sun's south pole, or is Cycle #24 about to leave the building? And will Cycle #25 be absent all together, as some researchers suggest? What role does the solar cycle play in the complex climate change puzzle? These next few years will be exciting ones for solar science, as the predictive significance of the HCS, SD and SL values are put to the test… and that’s what good science is all about!

February 2017

Sunday, February 5th: The Moon occults Aldebaran



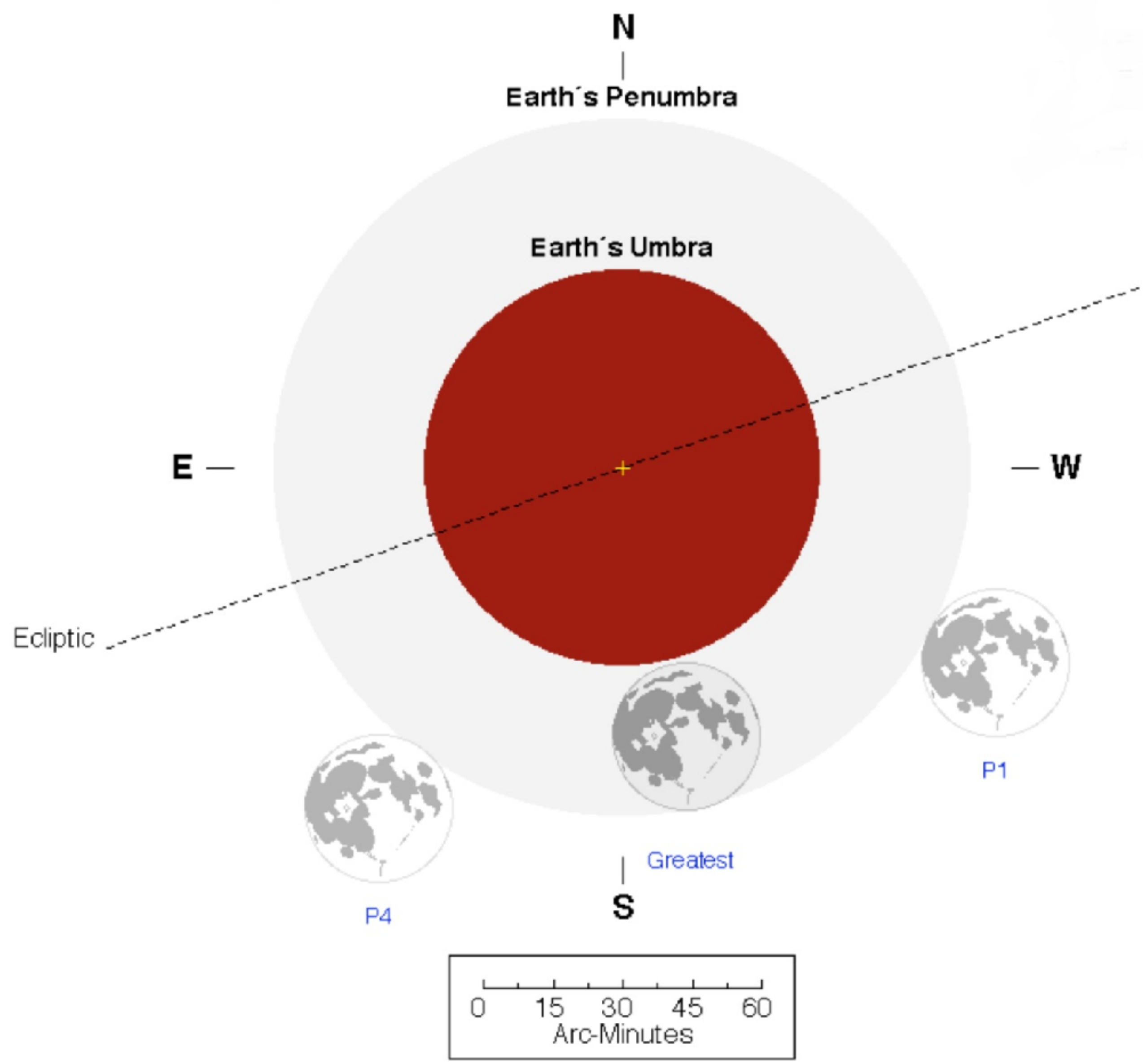
The footprint of the February 5th event. Image credit Occult 4.2

The 64% illuminated waxing gibbous Moon occults the +0.9 magnitude star Aldebaran. The Moon is one day past 1st Quarter during the event. Both are located 113 degrees east of the Sun at the time of the event. The central time of conjunction is 21:38 Universal Time (UT). The event occurs during the daylight hours over Central America and under darkness for the Mediterranean region, including Spain, Italy and northern Africa. The Moon will next occult Aldebaran on March 5th. This is occultation 28 in the current series of 49 running from January 29th , 2015 to September 3rd, 2018. This is the most central occultation of Aldebaran by the Moon for 2017.

The view from central Morocco around 21:46 UT. Image credit: Stellarium

The dark limb of the Moon leads its path during occultations in waxing phases, and then trails it past Full during waning phases.

Saturday, February 11th: A Penumbral Lunar Eclipse

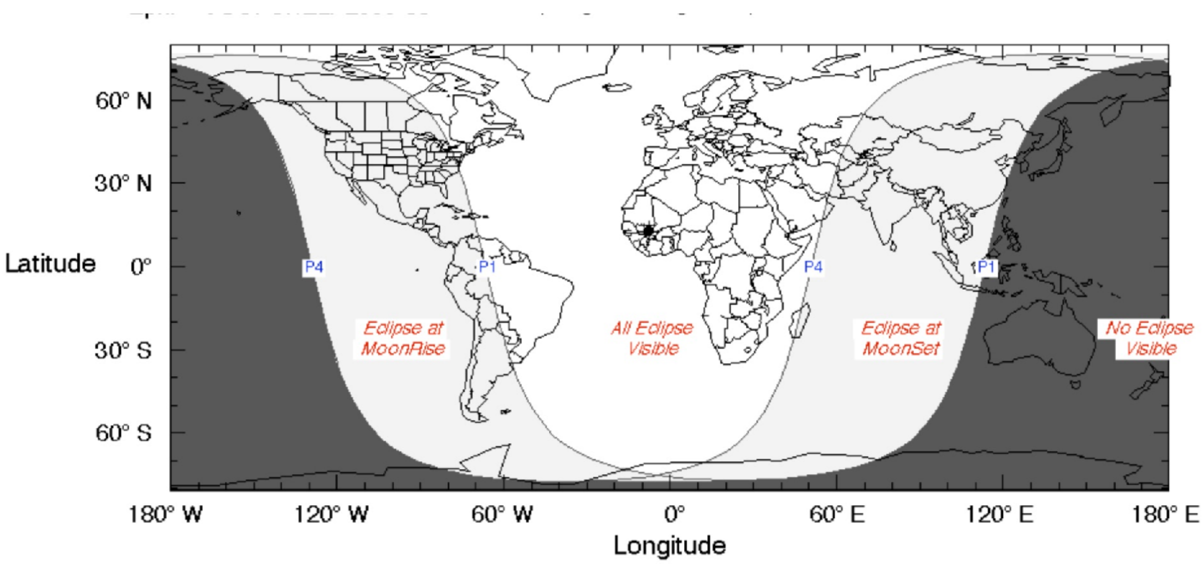


The path of the Moon through the Earth's shadow. Image credit: NASA/GSFC/F. Espenak

The Moon passes through the outer edge of the Earth's shadow from 22:34 (February 10th) to 2:53 Universal Time (UT) This is the **first eclipse for 2017**. This eclipse is penumbral only, with the Moon 99% immersed in the Earth's outer shadow at 00:43:53 UT. The eclipse is visible in its entirety from the Canadian Maritimes, Brazil, Africa, Europe and the Middle East.

The eclipse occurs at moonrise for the remainder of North and South America, and moonset for central Asia. This eclipse is member 59 of 71 for saros series 114, which began on May 13th, 971 AD and ends on June 22nd, 2233. This saros produced its last total lunar eclipse on July 17th, 1674. The next lunar eclipse is a partial on August 7th, 2017.

Keen-eyed observers may note a slight diffuse shading on the northeastern limb of the Moon around mid-eclipse.

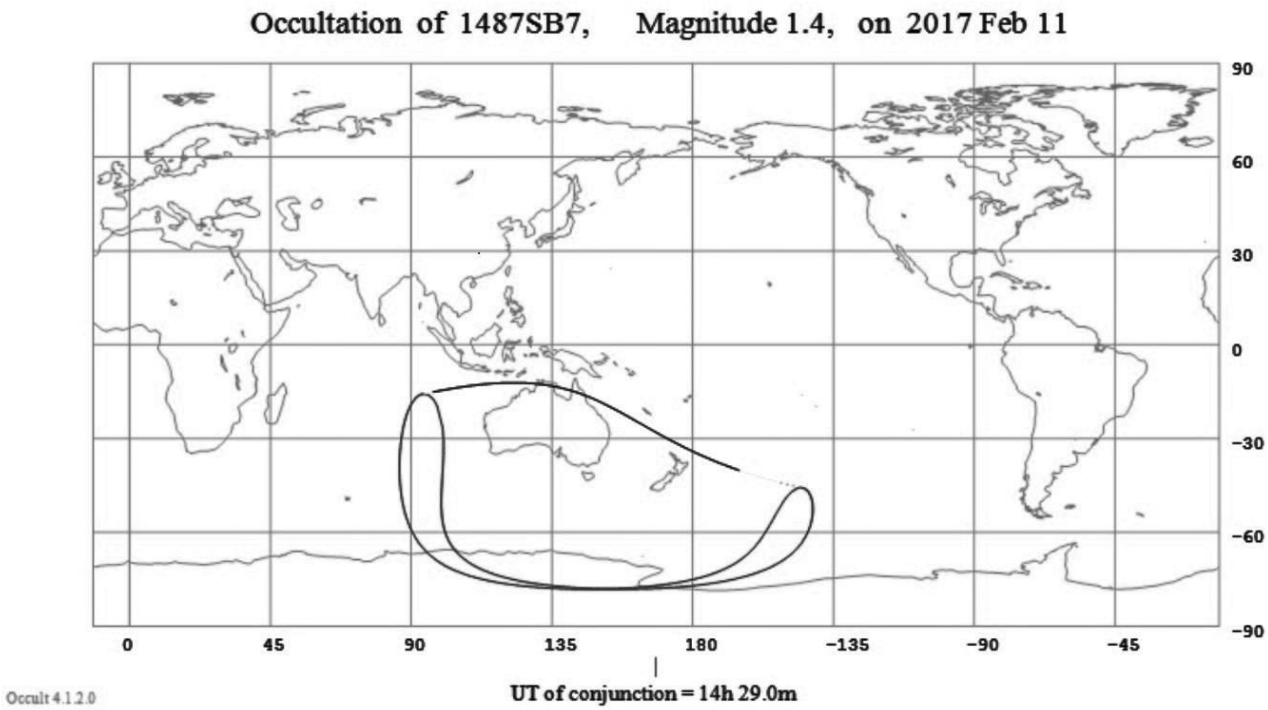


The visibility regions for the eclipse. Image credit: NASA/GSFC/F. Espenak

Although a lunar penumbral eclipse is the ultimate 'non-event' when it comes to eclipses – lunar or solar – you can indeed note the before, during and after differences photographically.

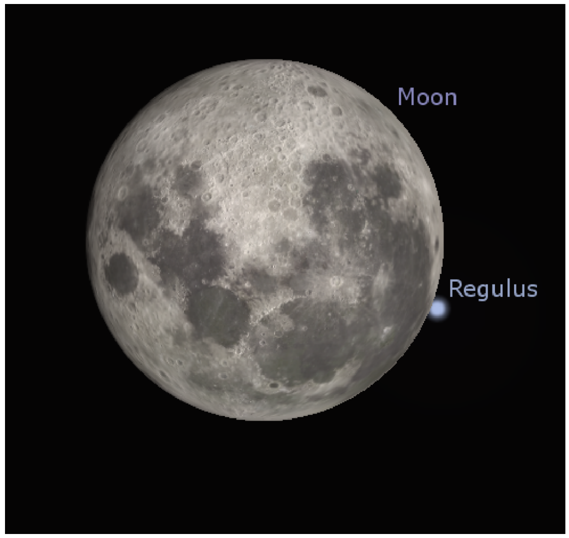
Penumbral Lunar Eclipse. Image credit: Christopher Jivanka - https://www.instagram.com/gamma_neo/

Saturday, February 11th: The Moon occults Regulus



The occultation footprint for the February 11th event. Image credit Occult 4.2

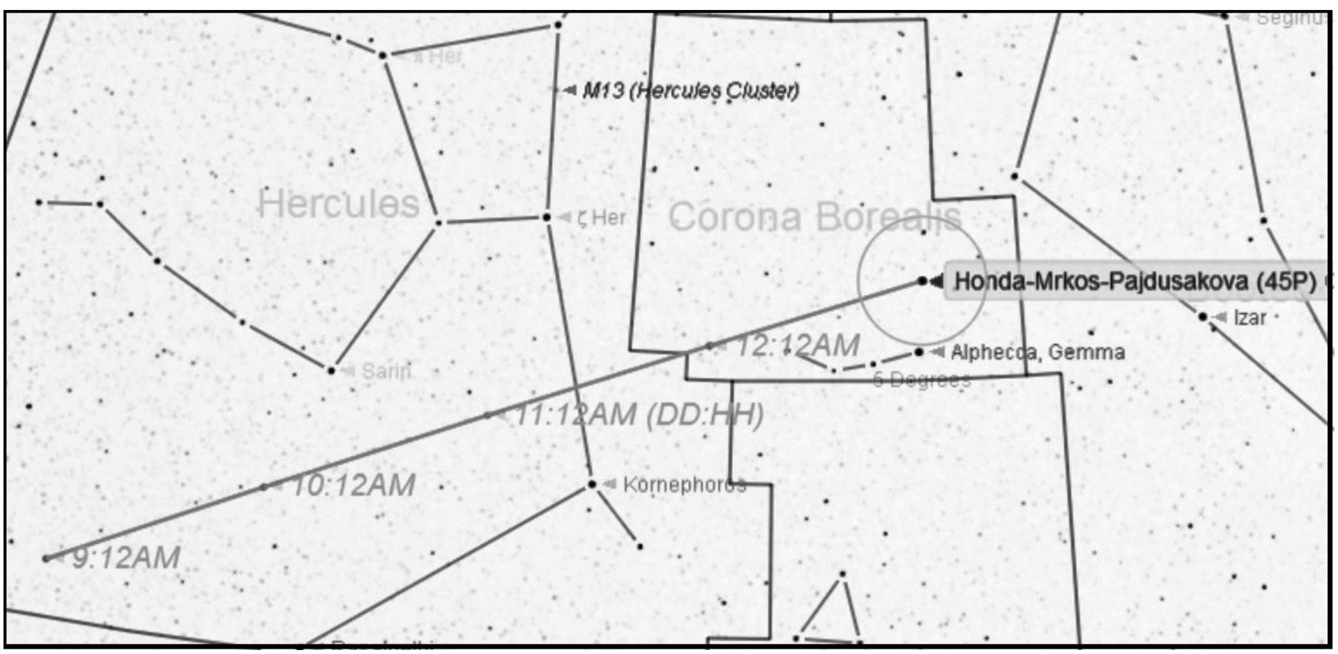
The 99% illuminated Moon occults the +1.4 magnitude star Regulus. The Moon is less than one day past Full during the event. Both are located 172 degrees west of the Sun at the time of the event. The central time of conjunction is 14:29 Universal Time (UT). The event occurs during the daylight hours over the South Pacific, and under darkness for Australia, including New Zealand and Tasmania. The Moon will next occult Regulus on March 11th. This is occultation 3 in the current series of 19 running from December 18th, 2016 to April 24th, 2018. This occultation occurs just 14 hours after a penumbral lunar eclipse on the same date.



The view from SE Australia prior to occultation. Image credit: Stellarium.

4 1st magnitude stars are on the Moon's path in the current epoch: Regulus, Aldebaran, Antares & Spica.

Saturday, February 11th-Comet 45P/Honda-Mrkos-Pajdušáková at its Brightest.



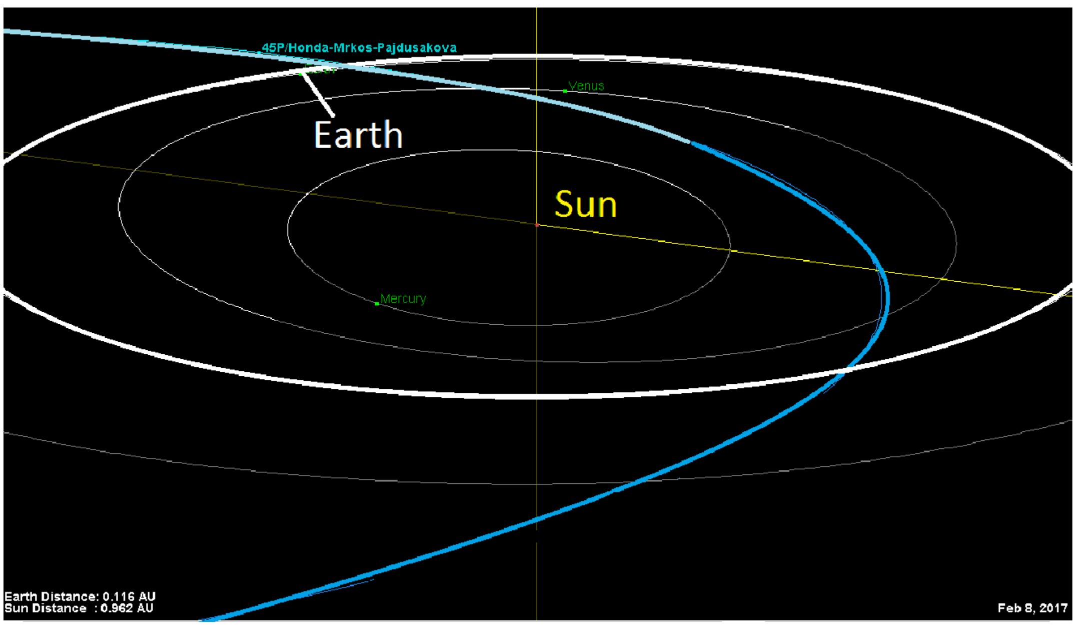
The swift path of Comet 5P/Honda-Mrkos-Pajdušáková on the nights of February 9th to February 12th. Image credit: Starry Night Education.

Comet 45P/Honda-Mrkos-Pajdušáková is expected to reach maximum brightness around this

date. Discovered independently by astronomers Minoru Honda, Antonin Mrkos and L'udmila Pajdušáková on December 3rd, 1948, Comet 45P/Honda-Mrkos-Pajdušáková orbits the Sun once every 5.25 years on a short period orbit. Comet 45P/Honda-Mrkos-Pajdušáková is set to break binocular +10th magnitude brightness in mid-December 2017, and may reach a maximum brightness of magnitude +7 from January 2017 through February.

Visibility prospects: At its brightest, Comet 45P/Honda-Mrkos-Pajdušáková will pass through constellations Hercules on closest approach and on through Corona Borealis, Boötes, Canes Venatici and Ursa Major into Leo through the end of February, and is best visible in the dawn sky 82 degrees west of the Sun at maximum brightness. This apparition favors the northern hemisphere. The comet reached perihelion on December 29th, 2016 0.53 AU from the Sun, and the comet passes just 0.08 AU (7.4 million miles) from the Earth on February 11th at 14:44 UT. At its closest, the comet will cross nine degrees of sky from one night to the next. Some notable dates in early 2017 for Comet 45P/Honda-Mrkos-Pajdušáková are:

January 10th: Crosses the ecliptic northward.
January 22nd: Passes near deep sky objects NGC 7009, M72 and M73.
January 25th: Passes 8 degrees from the Sun and into the dawn sky.
February 3rd: Crosses the celestial equator northward.
February 4th: Passes 4' from the +3.3 magnitude star Delta Aquarii.
February 6th: Crosses the galactic equator.
February 16th: Makes a wide pass near the globular cluster M3.

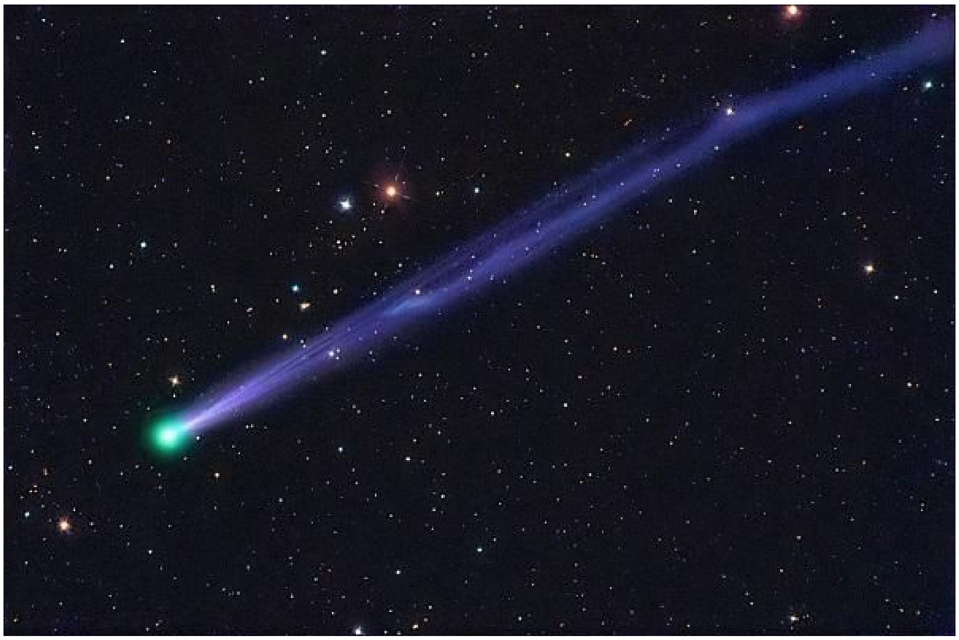


The path of Comet 45P/Honda-Mrkos-Pajdušáková through the inner solar system. Credit: NASA/JPL.

This is the final close (less than 0.1 AU) passage of Comet 45P/Honda-Mrkos-Pajdušáková

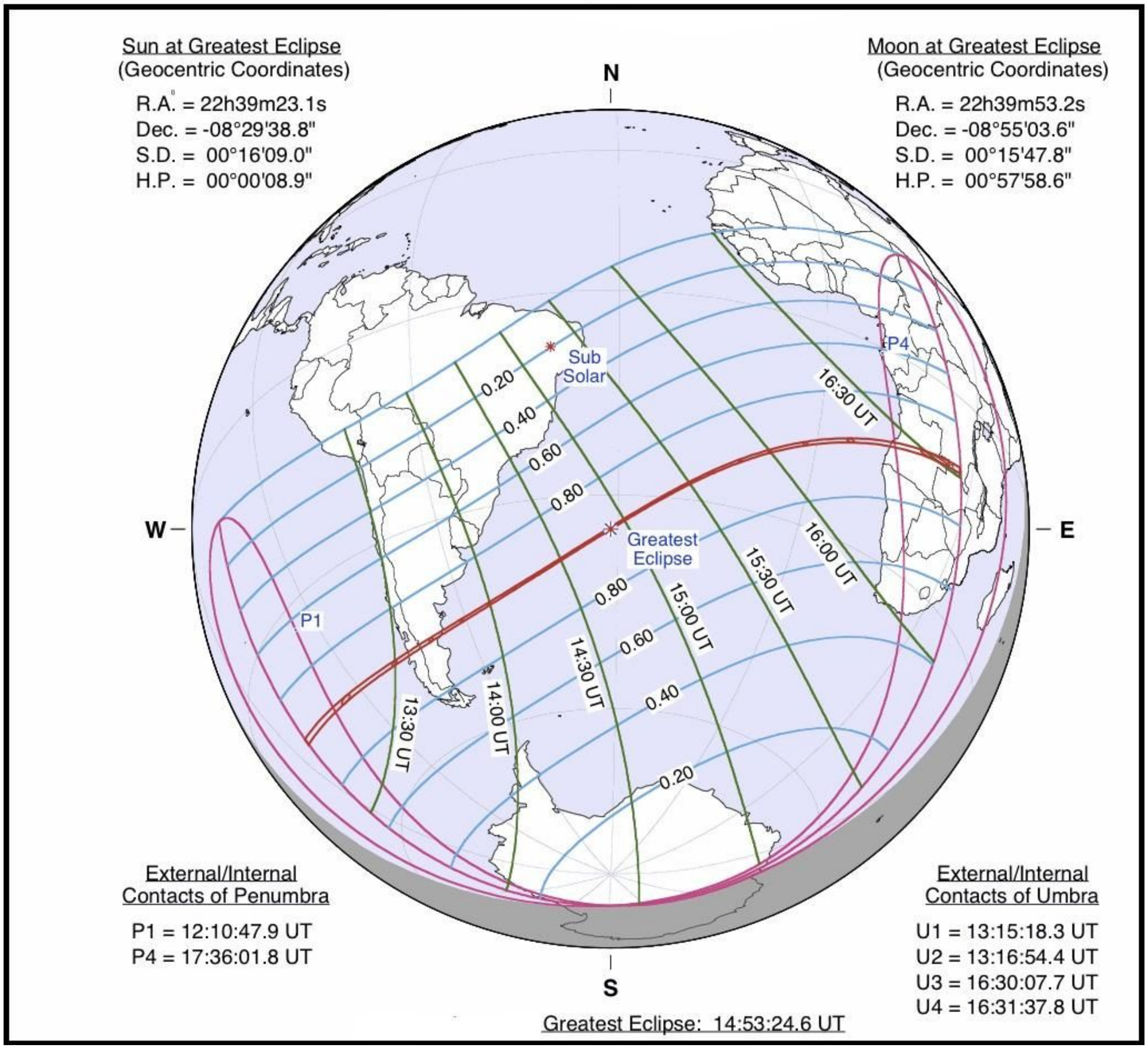
near the Earth for this century.

On July 1st 1770, Comet D/1770 L1 Lexell passed 0.0151AU from the Earth; a comet in 1491 may have passed closer. This year's passage of 45P/Honda-Mrkos-Pajdušáková ranks as the 21st closest recorded passage of a comet near the Earth.



Comet 45/P Honda-Mrkos-Pajdušáková from Oct 1st, 2011. Credit & copyright: Michael Jäager.

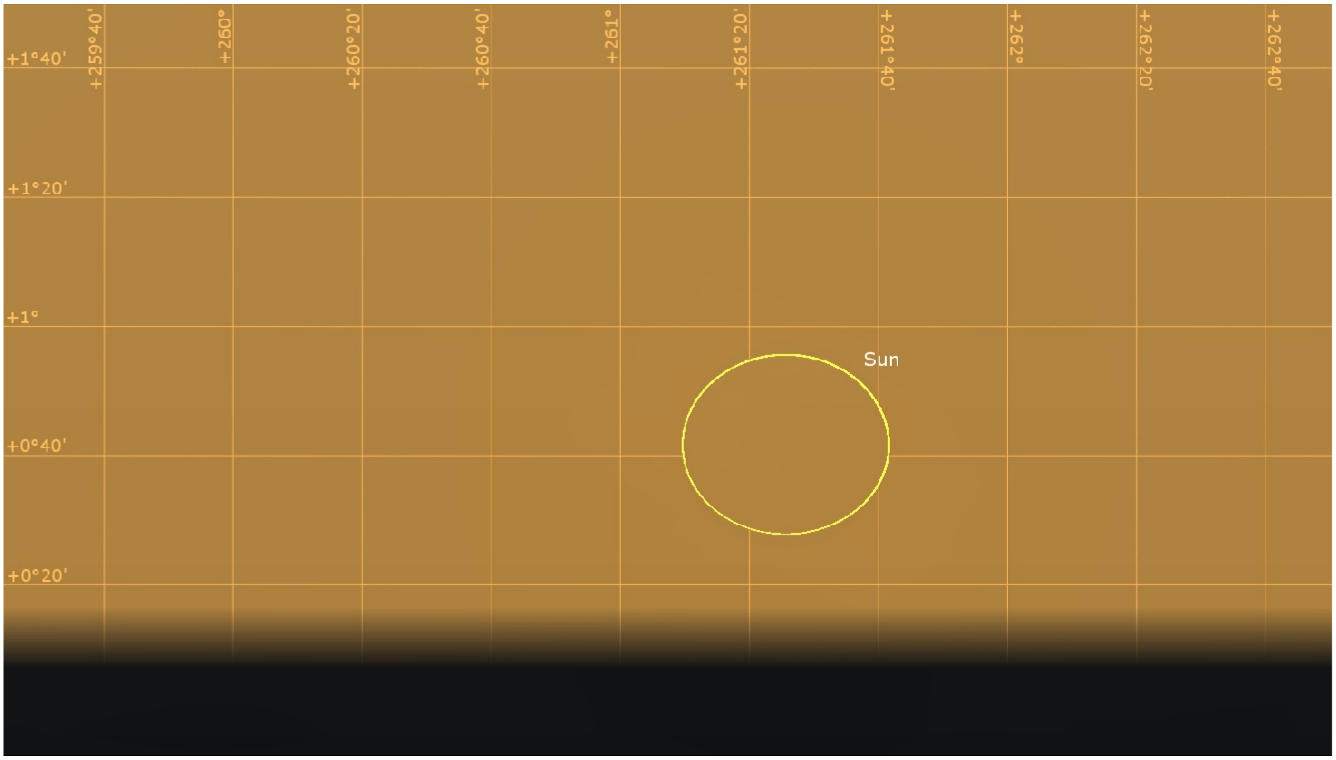
Sunday, February 26th: An Annular Solar Eclipse



The path of the February 26th annular solar eclipse. Credit: Fred Espenak/NASA/GSFC.

An annular eclipse of the Sun occurs. The path of the eclipse touches down in the Pacific, west of Chile at 13:15 Universal Time (UT). It then makes first landfall and crosses Chile and Argentina just a few minutes past 13:30 UT and reaches a 'greatest annularity' of 44 seconds in duration off of the coast of Brazil at 14:53 UT, with a maximum path width of 31 kilometers. The eclipse then crosses the coast of Angola in Africa just prior to 16:30 UT and sets during the final annular phase in Zambia and the southern Democratic Republic of the Congo before the antumbra departs the surface of the Earth at 16:31 UT. The partial phases of this eclipse run from 12:11 UT to 17:36 UT, and are visible across half of Antarctica, the southern half of South America, the Falkland Islands and southwestern Africa.

The Earth reached perihelion just over a month prior, while the Moon reached apogee just eight days prior to the eclipse. This means that the apparent size of the Moon (31.38') is too small to cover the 32.18' diameter Sun during the eclipse.



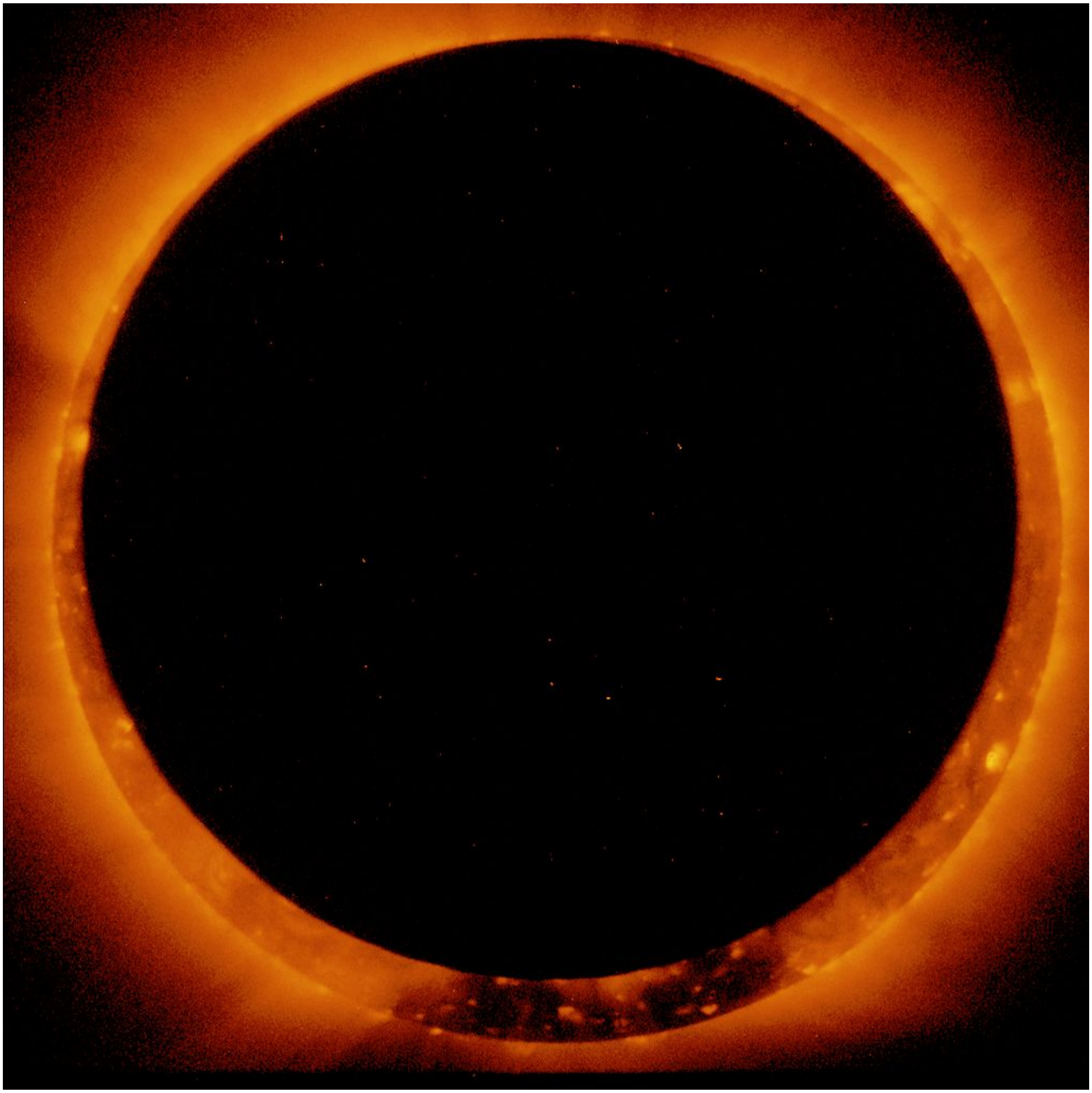
The annular eclipse at sunset as seen from Likasi, Democratic Republic of the Congo. Image credit: Stellarium.

Unlike a total solar eclipse, safety precautions must be taken observing all phases of an annular solar eclipse.

This is member 29 of the 71 eclipses in solar saros series 140, which runs from April 16th, 1512 to June 1st, 2774. This saros produced its last of 11 total solar eclipses on November 9th, 1836.

This is the only annular solar eclipse of 2017, and the final solar eclipse prior to the August 21st, 2017 total solar eclipse which crosses the contiguous 'lower 48' United States.

In our current epoch, annular eclipses are slightly more common than total solar eclipses. Looking at NASA's *Five Millennium Catalog of Eclipses* shows of the 11,898 solar eclipse from 2000 BC to 3000 AD, 4200 (35.3%) were partial, 3956 (33.2%) were annular, 3173 (26.7) were total and 569 (4.8%) were an annular-partial hybrid.



Annular solar eclipse captured by the Japanese Hinode spacecraft.

January's Challenge: Can You Spy Sirius B?

The coming years offer a once-in-a-lifetime chance to spot this unique star.

Artist's Impression of Sirius A/B. Credit: ESA/Hubble

Astronomy is all about thinking big in time and space.

The Earth turns on its axis, the Moon passes through its phases, and the planets come into opposition and solar conjunction on a routine basis.

Of course, on the other end of the spectrum, there are some events traversing such colossal periods of time that the mere mortal life span of measly *homo sapiens* such as ourselves can never expect to cover them. Many comets have periods measured in centuries or thousands of years. The axis of the Earth wobbles like a top, completing one turn every 26,000 years in what's known as the Precession of the Equinoxes. Our very own solar system completes one revolution about the galactic center every quarter billion years.

Feeling puny yet? Sure, astronomy is about humility. But among these stupendous cycles, there are some astronomical events that you just might be able to live through. One such instance is the orbit of some 'short period' double stars. In 2017, we challenge you to hunt for the most famous white dwarf of them all, as it reaches a favorable viewing position over the next few years: Sirius B.

Sirius itself is easy to find, as it’s the brightest star in Earth’s sky shining at magnitude -1.4 in the constellation Canis Major, Orion the Hunter's faithful right hand companion. In fact, Sirius is so bright that you can spot the star in the daytime sky if you know *exactly* where to look. Sirius rides high in the evening sky around March and April.

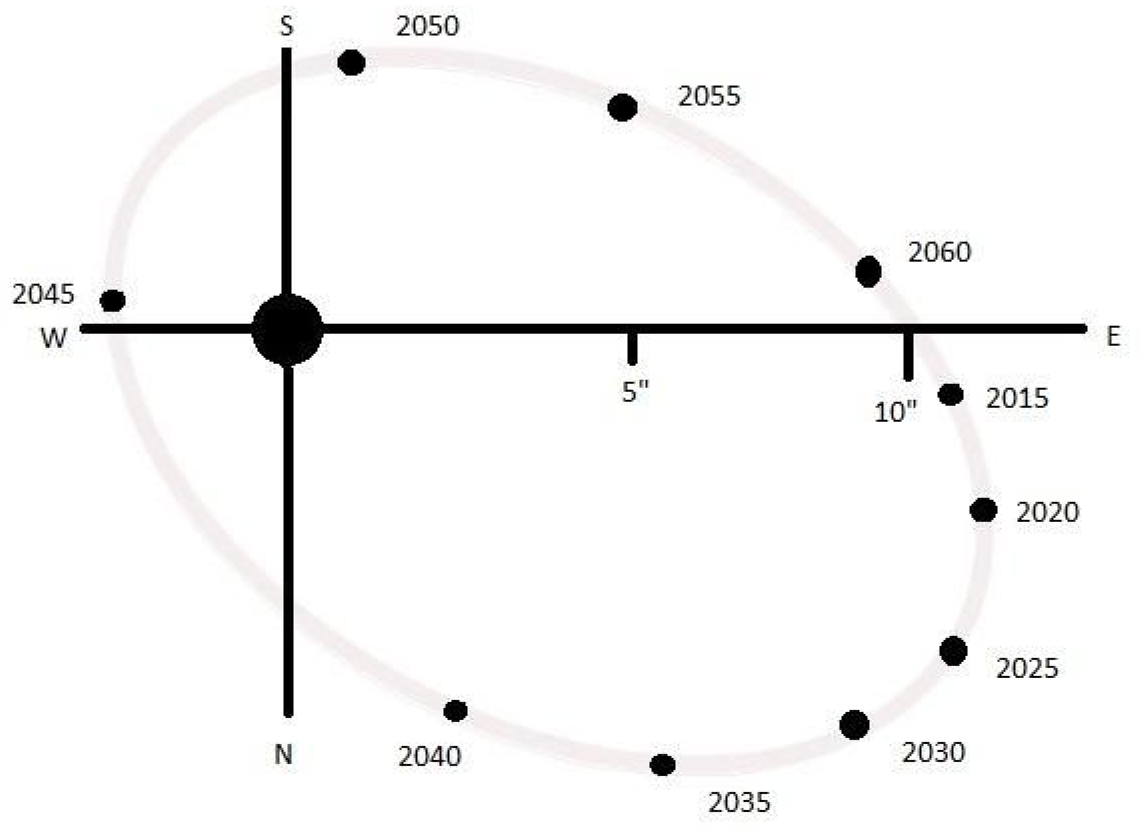
Looking south from latitude 40 north on March 1st. Image credit: Stellarium.

It's the ultimate cosmic irony: the most conspicuous of stars in our sky also hosts an elusive companion. The discovery of Sirius B awaited the invention of optics of such a quality as to resolve it next to its dazzling host. Alvan Clark Jr. and Sr. first spied the enigmatic companion on January 31st 1862 while testing their newly constructed 18.5 inch refractor, which was the largest at the time. The discovery was soon verified from the Harvard College Observatory, adding Sirius A and B to the growing list of multiple stars.

And what a strange companion it turned out to be. Today, we know that Sirius B is a white dwarf, the cooling dense ember of a main sequence star. We call such a star *degenerate*, not as commentary on its moral stature, but referring to the state the electrons and the closely packed nuclei in the star under extreme pressure. Our Sun will share the same ultimate fate as Sirius B, about six billion years from now.

The challenge, should you choose to accept it, is to spot Sirius B in the glare of its host. The contrast in brightness between the pair is daunting: shining at magnitude +11, the B companion is more than 63,000 times fainter than -1.4 magnitude Sirius A.

A feat of visual athletics, indeed. Still, Sirius B broke 10" in separation from its primary in 2015, as it heads towards apastron — its most distant point from its primary, at just over 11" in separation — in 2019. Sirius B varies from 8.2 and 31.5 Astronomical Units (AU) from its primary. Sirius B is on a 50.1 year orbit, meaning the time to cross this one off of your life list is over the upcoming decade. Perhaps making an animation showing the motion of Sirius B from 2015-2025 would present a supreme challenge as well.



The orbit of Sirius B from 2015 to 2066. Graphic by author.

Sirius culminates at local midnight right around New Year's Eve, shining at its highest to the south as the "ball drops" ushering in 2017. Of course, this is only a fortuitous circumstance

that is possible in our current epoch, and precession and the proper motions of both Sirius and Sol will make this less so millennia hence.

Magnification and good seeing are your friends in the hunt for Sirius B. Two factors describe the position of a secondary star in a binary pair: its position angle in degrees, and separation in arc seconds. When it comes to stars that are a tough split, I find its better to estimate the position angle first before looking it up. A close match can often confirm the observation. Does a friend see the same thing at the eyepiece? A good star to “warm up” on is the +6.8 magnitude companion to Rigel in the foot of Orion, with a separation of 9”.

A homemade 'occulting bar' eyepiece. Image by author.

Nudging Sirius just out of view might allow the B companion to become apparent. Another nifty star-splitting tool is what’s known as an occulting bar eyepiece. Making an occultation bar eyepiece is easy: we’ve used everything from a small strip of foil to a piece of guitar string (heavy E gauge works nicely) for the central bar. An occulting bar eyepiece is also handy for hunting down the moons of Mars near opposition.

Sirius B also works its way into cultural myths and lore, not the least of which is the curious tales of the Dogon people of Mali. At the outset, it seems that these ancient people have knowledge of a small dense hidden companion star to Sirius, knowledge that requires modern technology to reproduce. Carl Sagan noted, however, that cultural contamination may have resulted in the late 19th century discovery of Sirius B making its way into the Dogon pantheon. The science of anthropology is rife with anecdotes that have been carefully fed to credulous anthropologists only to be reported as fact, all in the name of a good story.

All amazing things to ponder as you begin your 2017 quest for Sirius B, a bashful but fascinating star.

March 2017

Wednesday, March 1st: Zodiacal Light Season Begins

The zodiacal light in the Nevada dawn. The plane of the ecliptic can be traced by Jupiter in Gemini & Mars in the Beehive cluster just below center. (Credit: Cory Schmitz - https://photographingspace.com/).

Zodiacal light season begins, as the Sun approaches the March (northward equinox). This is a backscattering of light off of dust particles spread out along the ecliptic plane. Spring and Fall are the best times to see this pearly glow in the dawn or dusk. This is because of the steep angle of the ecliptic relative to the horizon during the equinox season. The March equinox season favors dawn for the southern hemisphere and dusk for the northern hemisphere; the reverse is true near the September equinox.

To see the zodiacal light, start your vigil around an hour after sunset or an hour before dawn, and observe from as dark a site as possible. Any light pollution or faint glows from distant

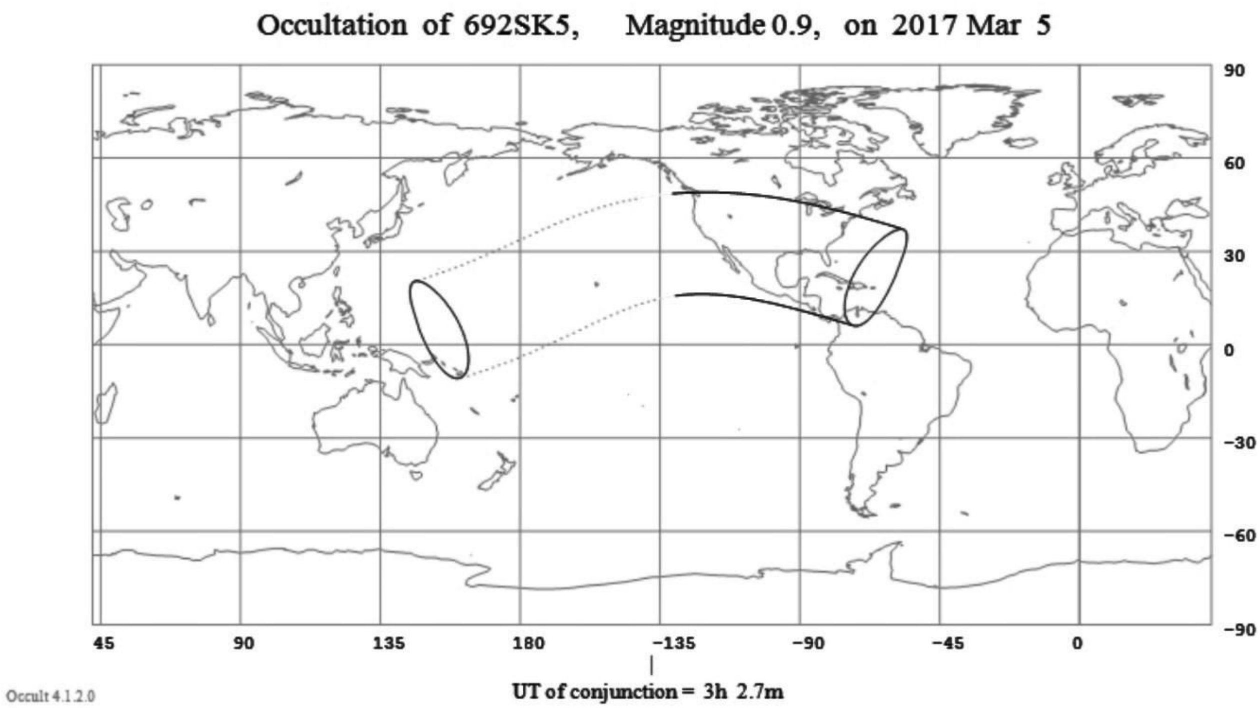
cities on the horizon can kill the ethereal glow. The zodiacal light will appear as a slender pyramid-shaped glow, tracing the length of the ecliptic plane.

A related counter-glow known as the *gegenschein* can also occasionally be seen at the anti-sunward point at local midnight under pristine dark skies.

For reasons still not completely understood, auroral activity is also slightly enhanced right around either equinox.

Queen guitarist Brian May finished his PhD thesis in astronomy on the zodiacal light titled *A Survey of Radial Velocities in the Zodiacal Dust Cloud* in 2007. May started this thesis 37 years earlier.

Sunday, March 5th: The Moon occults Aldebaran



The occultation footprint for the March 5th event. Image credit: Occult 4.2.

The 46% illuminated waxing crescent Moon occults the +0.9 magnitude star Aldebaran. The Moon is seven days past New during the event. Both are located 85 degrees east of the Sun at the time of the event. The central time of conjunction is 3:03 Universal Time (UT). The event occurs during the daylight hours over the central Pacific and Hawaii, and under darkness for southern North America, including most of the contiguous United States and Mexico. The Moon will next occult Aldebaran on April 1st. This is occultation 29 in the current series of 49 running from January 29th, 2015 to September 3rd, 2018. This is the best evening

occultation of Aldebaran by the Moon for North America in 2017.

The view on March 5th from the southern U.S. Image credit: Stellarium.

In the current century, (2001-2100 AD) the Moon occults Aldebaran 247 times, topped only by Antares (386 times) and barely beating out Spica (220 times).

Friday, March 10th: The Moon occults Regulus

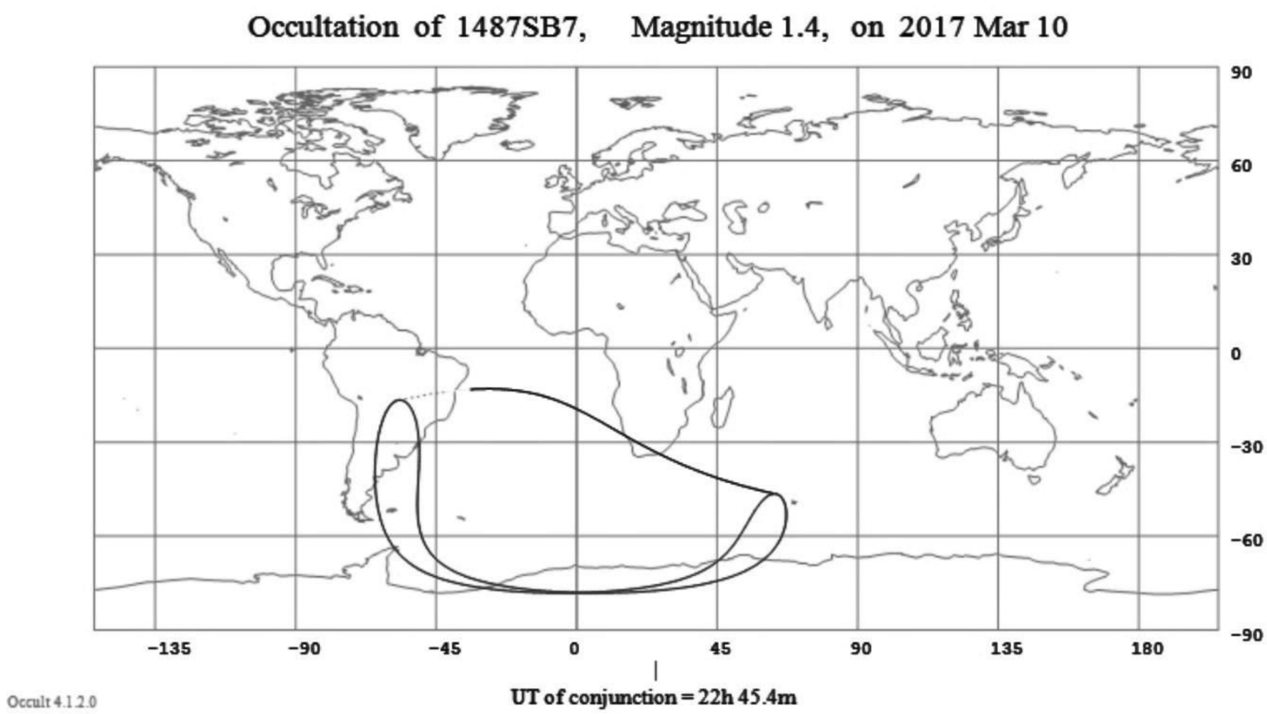
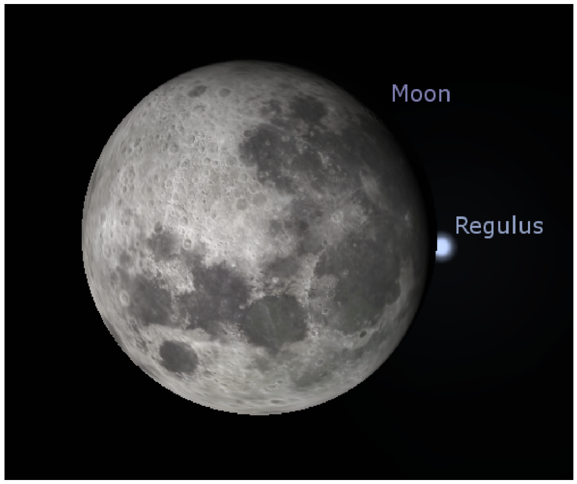


Image credit Occult 4.2

The 97% illuminated waxing gibbous Moon occults the +1.4 magnitude star Regulus. The Moon is 2 days prior to Full during the event. Both are located 159 degrees east of the Sun at

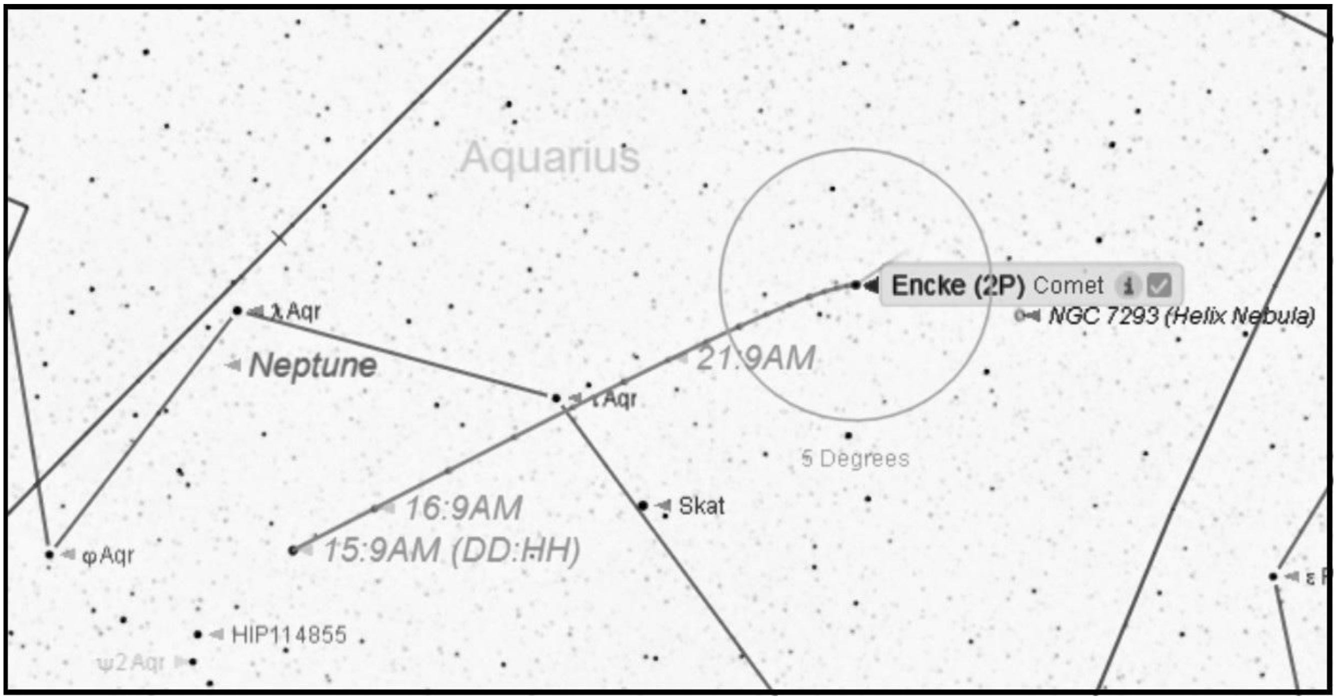
the time of the event. The central time of conjunction is 22:45 Universal Time (UT). The event occurs during the daylight hours over Brazil, and under darkness for the southernmost tip of Africa, including Cape Town South Africa. The Moon will next occult Regulus on April 7th. This is occultation is the 4th in the current series of 19 running from December 18th, 2016 to April 24th, 2018. Observers to the northeast of Cape Town will be treated to a fine graze of Regulus along the Moon's northern limb.



The view on March 10th. Image credit: Stellarium

Astronomers use observations of grazing occultations — often made by amateurs — to map the profile of the lunar limb.

Wednesday, March 15th: Comet 2P Encke at its Brightest

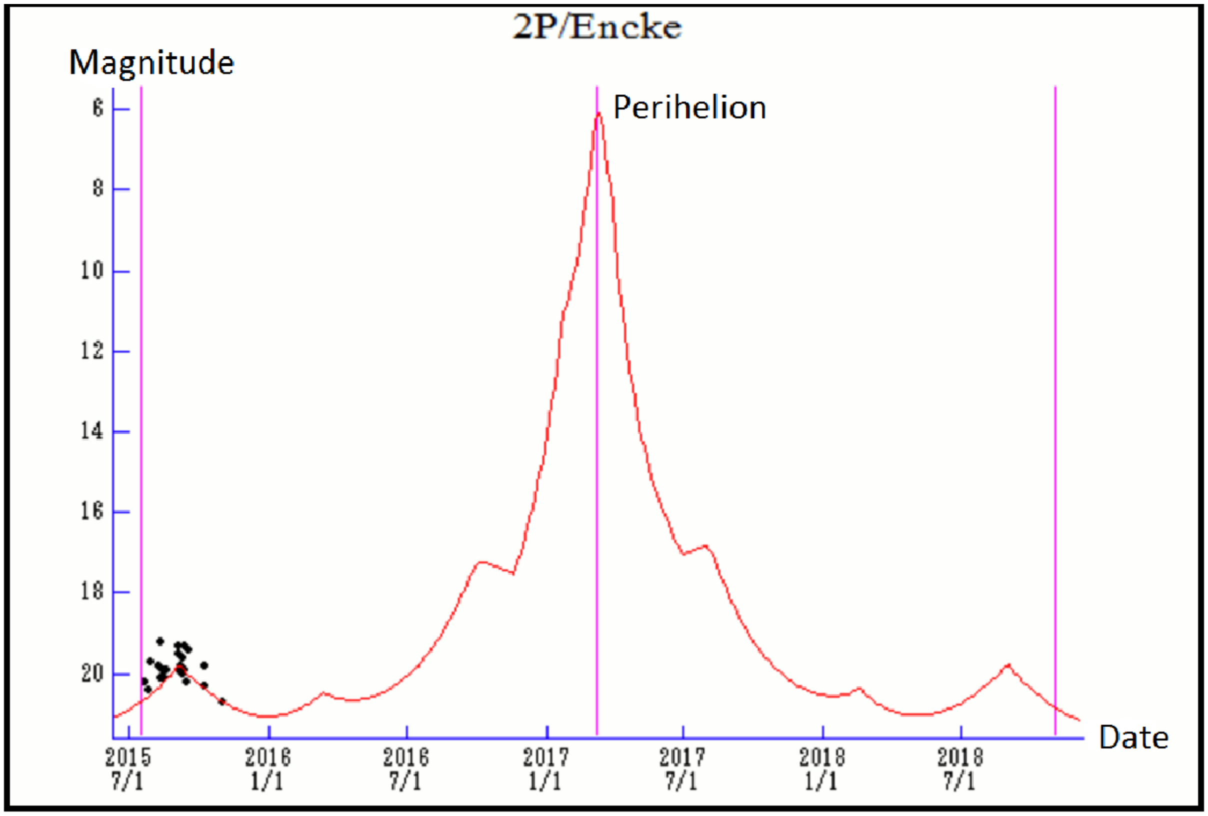


The path of Comet 2P Encke from March 15th to March 30th. Credit: Starry Night.

Comet 2P Encke is expected to reach maximum brightness around this date. Discovered by Pierre Méchain in 1786, periodic Comet 2P Encke orbits the Sun once every 3.3 years on a long short period orbit. Comet 2P Encke is set to break binocular +10th magnitude brightness in mid-January 2017, and may reach a maximum +6th magnitude (naked eye brightness) by mid-March.

Comet 2P/Encke as imaged by Damian Peach on October 12th. (Credit: D. Peach)

Visibility prospects: At its brightest, Comet 2P Encke will pass through the astronomical constellations of Pisces and Aquarius in January through May. It is, however, very close to the Sun (11 degrees on March 15th) at its brightest. Comet 2P Encke is best visible in the dusk sky 35 degrees east the Sun around February 15th, and then reaches 30 degrees and greater elongation west of the Sun in the dawn sky from March 20th onward. 2P Encke will cross SOHO's 15 degree field of view from March 9th to the 13th. This apparition favors the northern hemisphere for the evening apparition and the southern for the morning appearance. Comet 2P Encke reaches perihelion on March 10th at 0.33 AU from the Sun. Close approaches to the Earth occur once every 30-33 years, with the next being a 0.4 AU from the Earth in 2036.



The projected brightness for 2P Encke through 2016-2018. Credit: Seiichi Yoshida's *Weekly Information About Bright Comets.*

Some key dates for Comet 2P Encke are:

February 7th – Passes 5 degrees from Venus.
March 8th – Crosses the celestial equator southward.
March 9th – Crosses the ecliptic southward.
March 11th – Reaches solar conjunction 2 degrees from the Sun.
April 4th – Passes near the Helix Nebula (NGC 7293).

Comet 2P Encke has the shortest orbital period of any bright comet.

Comet 2P Encke is the source of the November Taurid fireballs.

Monday, March 20th The March Equinox

Sunrise by Cory Schmitz @theastroshake, https://PhotographingSpace.com

The northward equinox occurs at 10:28 Universal Time (UT), marking the beginning of astronomical Spring for the northern hemisphere, and the start of Fall for the southern. This is an exact moment when the Sun's declination equals 0 as seen from the Earth. The two points where the ecliptic or the imaginary path the Sun seems to trace out along the celestial sphere meets the equator are known as the *equinoctial points*.

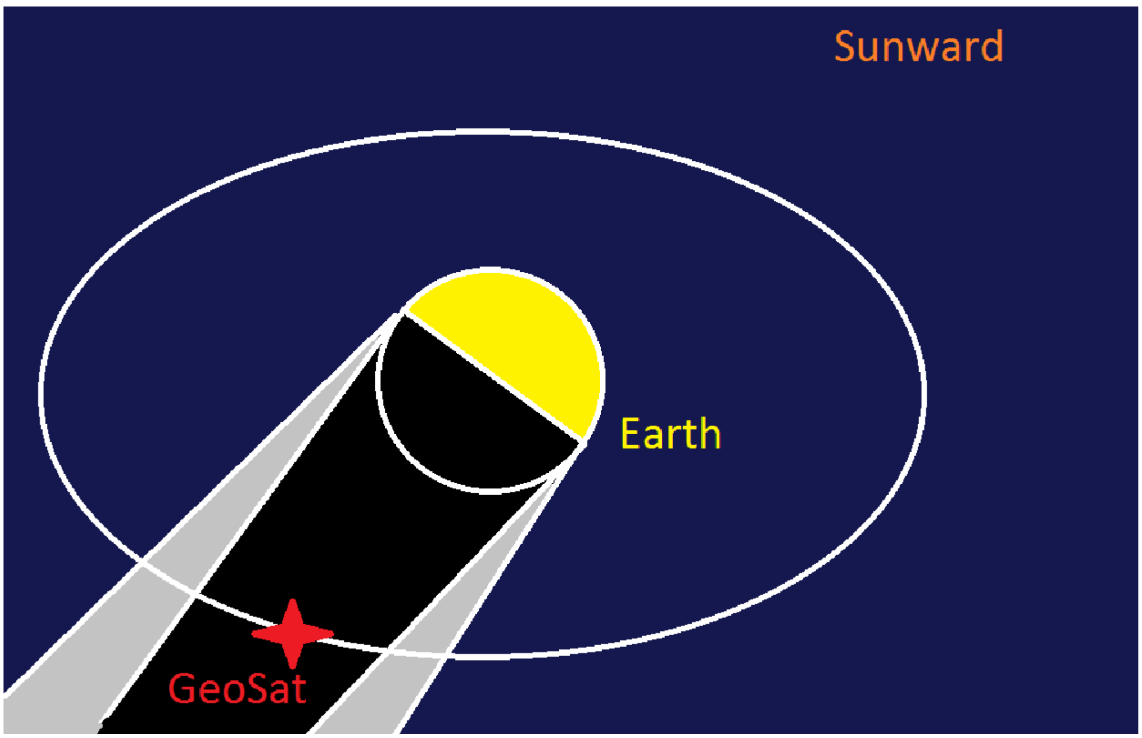
In the 21st century, the March Equinox last fell on March 21st on 2007, and will continue to fall on March 21st until 2044, when it will begin occurring on March 19th every fourth year.

The Equinox (literally meaning 'equal night' in Latin) means that night and day are nearly equal worldwide, and that the Sun rises due east of an observer on each equinox and sets to the west.

We say night and day are nearly equal, because the instantaneous nature of the equinox, combined with atmospheric refraction near sunset and sunrise, the position of the observer in their particular time zone and the fact that the Sun isn't a point of light but a sphere with an apparent diameter of 30' across means that the actual time that the length of daylight and nighttime are equal (known as the *equilux*) can vary a few days on either side of the equinox.

The March Equinox is used by the Roman Catholic Church to fix the date for Easter as the first Sunday after the First Full Moon after March 21st (the perpetual date the Church uses for the March Equinox).

Tuesday, March 21st: The middle of GEO satellite eclipse season



A geostationary satellite in the Earth's shadow. Graphic by author.

Geostationary satellite flare and eclipse season occurs. This is a three week span, centered on either equinox for any given year. Orbiting the Earth at a distance of 35,785 kilometers distant, these satellites are only normally visible only in a large telescope at around +12th magnitude. Just prior to entering the Earth's shadow, however, a geostationary satellite can, on occasion, flare up briefly to naked eye visibility. The Earth's shadow is larger at geostationary distance than it is as seen at the Moon's distance during a lunar eclipse, and eclipses of geosats can last up to 68 minutes in duration. GeoSat flares frequently turn up on long exposure shots of the night sky.

What you're seeing during a satellite flare event is the specular reflection of the Sun off of the satellite's solar panels. Most of the satellites visible to the unaided eye are in low Earth orbit, a few hundred kilometers above the Earth and whizzing along once around the Earth every 90 minutes.

The most famous of the class of flaring satellites belong to the Iridium constellation of communications satellites in low Earth orbit.

Users of geostationary communications satellites typically experience relay blackouts of sunward satellites around each equinox season as well, as must account for these anticipated blackout seasons every six months.

https://www.calsky.com/?geosat=

The first successful geostationary satellite was Syncom 2, launched on July 26th, 1963.

Adventures in Satellite Spotting

On hunting and following human built 'stars' in the sky.

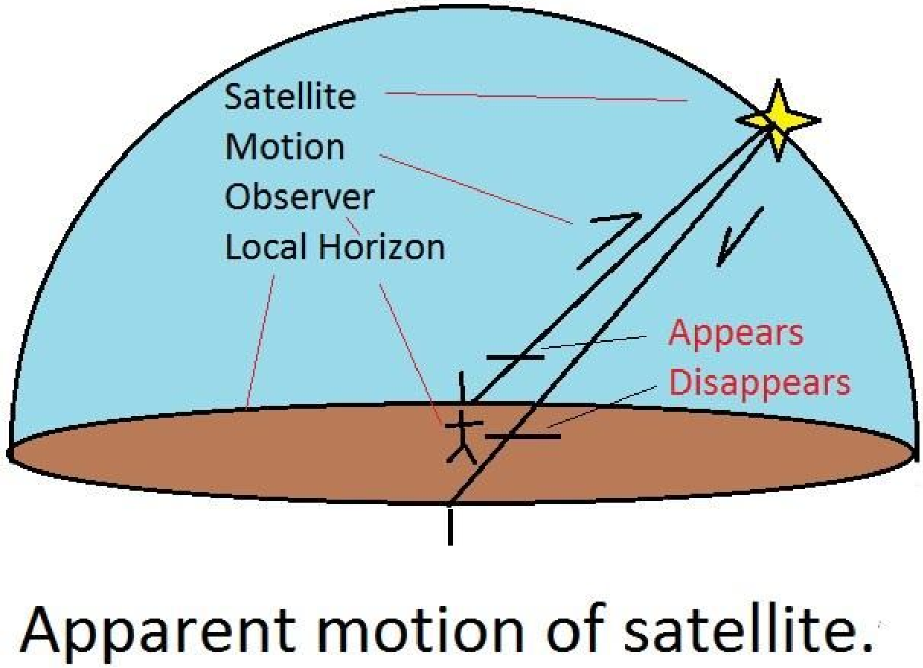
Milky Way with a few satellites “ruining” the image. Credit: Fraser Cain, processing by Cory Schmitz from [PhotographingSpace.com]()

It’s a question we get all the time.

Watch the sky closely in the dawn or dusk hours, and you’ll likely see a moving 'star' slowly sliding by. This is a satellite, an “artificial moon” placed in low Earth orbit. These shine via reflected sunlight as they pass hundreds of kilometers overhead.

Many folks are unaware that you can see satellites with the naked eye. I always make a point to watch for these during public star parties. A bright pass of the International Space Station is often as memorable as anything that can be seen through the eyepiece. But after this revelation, the 'question' soon follows: “What satellite is that?”

Welcome to the wonderful and highly addictive world of satellite tracking. Ground-based observers have been watching the skies since the first satellite launch of Sputnik 1 in October 1957. Armies of dedicated volunteers even participated in tracking the early launches of the Space Age, with Project Moonwatch.

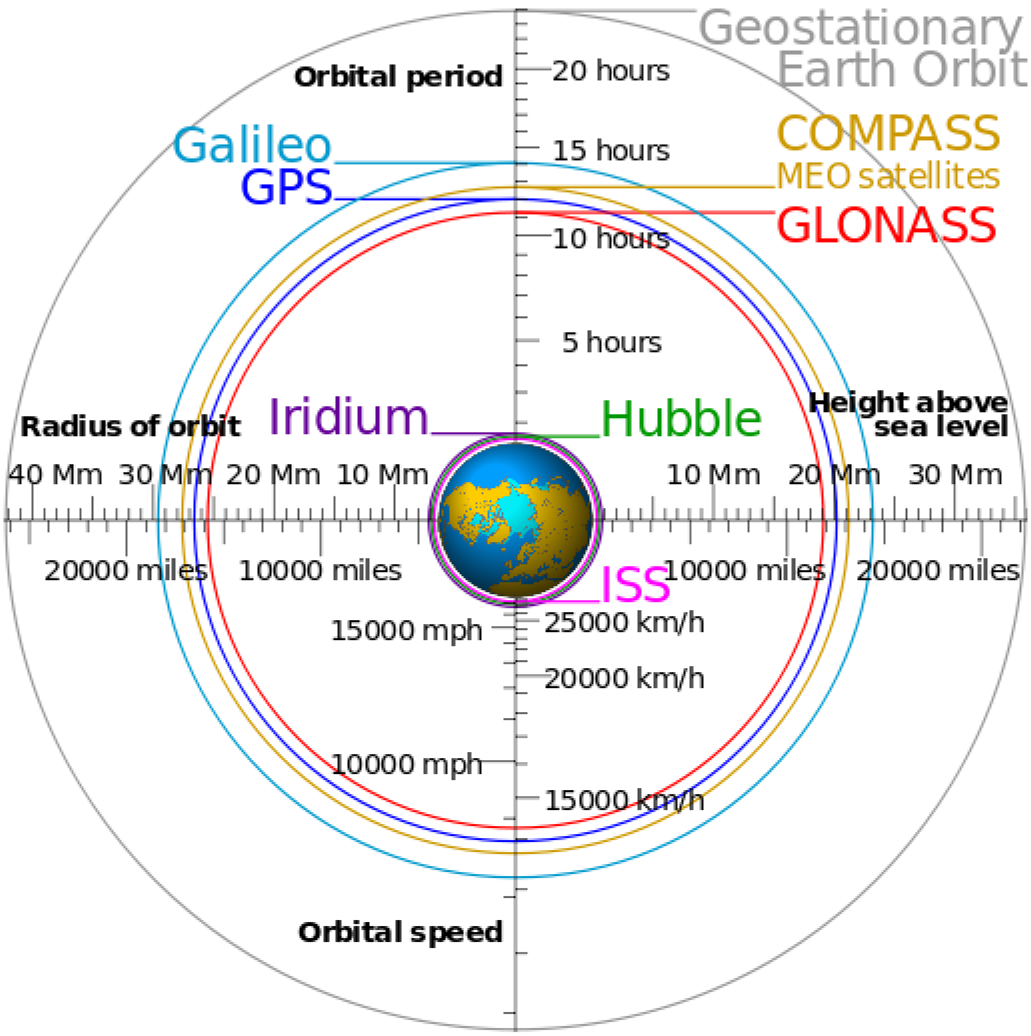


The apparent path of a satellite overhead. Graphic by the author.

The Internet offers a wealth of information for satellite hunters. Every time I write about "how to spot the ISS," someone amazes me with yet another new tracking website or app that I haven't heard of. One of my favorites is still Heavens-Above. It's strange to think, we've been visiting this outstanding website for a decade and a half now. Heavens-Above specializes in satellites, and will show you a quick listing of passes for brighter satellites tonight, once configured with your location. A nifty and simple way to 'quick check' and possibly resolve the identity of a mystery satellite is to use their link for 'Daily Predictions for Brighter Satellites,' which will generate a list of visible passes by time.

A Baker-Nunn camera dedicated to satellite tracking, now on display at the Evergreen Air and Space Museum. Photo by author.

Looking at the time, direction, and brightness of a pass is crucial to satellite identification. No equipment is needed to hunt for satellites tonight, just a working set of eyes and information. We sometimes use a pair of Canon image-stabilized 15x 45 binoculars to hunt for satellites too faint to see with the naked eye. We've seen the "Tool Bag" lost during an ISS EVA, Canada's first satellite Alloutte-1, and the old Vanguards (Yes, they're STILL up there!) using our trusty binocs.



Paths of various types of orbits. Image credit: Wikimedia Commons.

The trick to catching fainter satellites such as these is to “ambush” them. First, you’ll need to note the precise time that the selected satellite is going to pass near a bright star. Clicking on a selected satellite pass in Heavens-Above will give you a sky chart with a time-marked path. I then use a short wave portable AM radio tuned to WWV out of Fort Collins, Colorado for an audible time signal. Just sit back, listen to the radio call out the time, and watch for the satellite to pass through the field of view.

Another great site for more advanced trackers is CALSky. Like Heavens-Above, CALSky will give you a customized list for satellite passes over your location. One cool extra feature on CALSky is the ability to set alerts for passes of the ISS near bright planets or transiting the Sun or Moon. These are difficult events to capture, but worth it!

The International Space Station... plus space shuttle Atlantis! Photo by author.

A great deal of what's up there is space junk in the form of discarded hardware. Many satellites are on looping elliptical orbits, only visible to the naked eye when they are near perigee. Many satellites are located out at distant geosynchronous or geostationary orbits and are usually invisible to the naked eye all together. These will often show up as streaks in astrophotos. An area notorious for geosynchronous satellites exists near the direction of M42 or Orion Nebula. At certain times of year, satellites can be seen nearby, nodding slowly north to south and back again. Around the March and September equinox seasons, geostationary satellites can be eclipsed by the shadow of the Earth. This can also cause communications difficulties, as many geo-sats also lie sunward as seen from the Earth around these times of year.

Probably one of the simplest satellite trackers for users is Space Weather's *Satellite Flybys* page. North American users simply need to enter a postal code (worldwide users can track satellites via entering 'country-state-city') and a list of passes for your location is generated.

It's a basic truism of satellite tracking that "aircraft blink; satellites don't". Now, we're going to present an exception to this rule.

Some satellites will flash rhythmically due to a tumbling motion. This can be pretty dramatic to see. What you're seeing is usually a cylinder-shaped expended booster, tumbling end-over-end due to atmospheric drag. Some satellites can flash or flare briefly due to sunlight glinting off of reflective surfaces if it strikes them just right. Hubble, the ISS and the late NanoSail D2 can flare on occasion as well.

The most dramatic of these are Iridium flares. The Iridium constellation consists of 66 active satellites in low-Earth orbit used for satellite phone coverage. When one of their three refrigerator-sized antennas catch the Sun just right, they can flare up to magnitude -8, or 40

times brighter than Venus. CALSky and Heavens-Above will also predict these events for your location.

Didn’t see a predicted satellite pass? Light pollution or bright twilight skies might be to blame. Keep in mind, passes lower to the horizon also fall prey to atmospheric extinction, as you’re looking through a thicker layer of the air than straight overhead. Some satellites, such as the ISS or the USAF’s X-37B spy space plane even periodically boost or modify their orbits, throwing off online prediction platforms for a time.

More advanced satellite trackers will also want to check out Celestrak and SAT-Flare Tracker 3D.

An example of a typical orbital Two Line Element. Image credit: Celestrak.

I frequently use a free tracking platform created by Sebastian Stoff known as Orbitron. Orbitron lets you set your observing location and tailor your view for satellites that are currently overhead. You can run simulations and even filter for 'visual only' passes, another plus. I also like Orbitron’s ability to run as a stand-alone system in the field, sans Internet connection. Just remember: for Orbitron to work properly, you’ll need to periodically update the .txt file containing the Two-Line Element (TLE) sets. TLEs are data element sets that describe the orbital elements of a satellite. Cut and paste TLEs are available from Heavens-Above, Celestrak and approved users of NORAD's Space-Track, the original source for most Two-Line Elements

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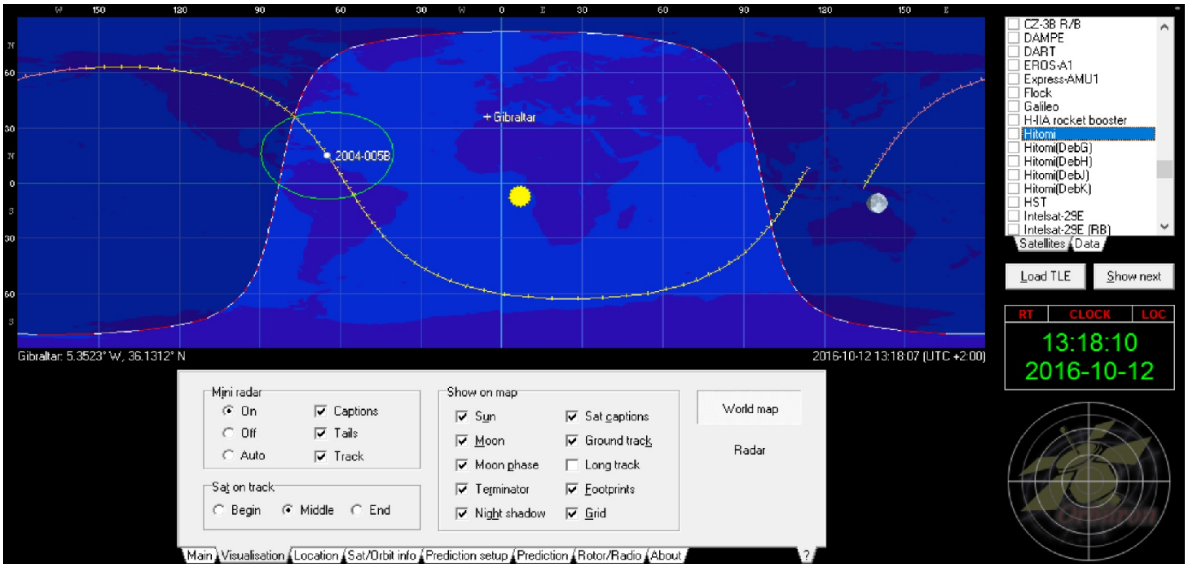
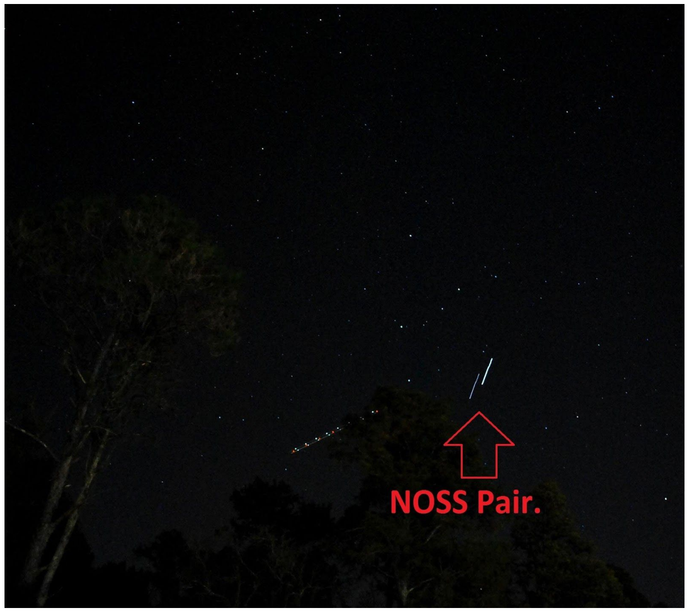


An Orbitron screenshot.

For serious users, NORAD's Space-Track is the best site for up to date TLEs. Space-Track requires a login and user agreement to access, but is available to the public for satellite spotters and educators as a valuable resource. Space-Track also hosts a table of upcoming reentries, as does the Aerospace Corporation's Center for Orbital & Reentry Debris Studies. The See-Sat mailing list is also an excellent source of discussions among satellite trackers worldwide. Increasingly, this sort of cross-talk is also moving over to Twitter, which is ideal for following swiftly evolving action in orbit.

And there's always something new or strange in the sky to see for the observant. Satellites such as NOSS are launched in groups and are eerie to watch as they move in formations of 2 or 3 across the sky. These are difficult to catch: all three of our sightings of a NOSS pair have been by pure luck. And thus far, we've only had the camera ready exactly once to swing into action and nab a NOSS pair:



A NOSS pairing. Photo by author.

Another bizarre satellite to catch in action is known as the Cloud-Aerosol Lidar & Infrared Pathfinder Satellite for Observations, or CALIPSO. Part of the afternoon 'A-Train' of sun-synchronous Earth-observing satellites, you can catch the green LIDAR flashes of CALIPSO from the ground with careful planning. NASA even publishes a prediction table for LIDAR passes. I wonder how many UFO sightings CALIPSO has generated?

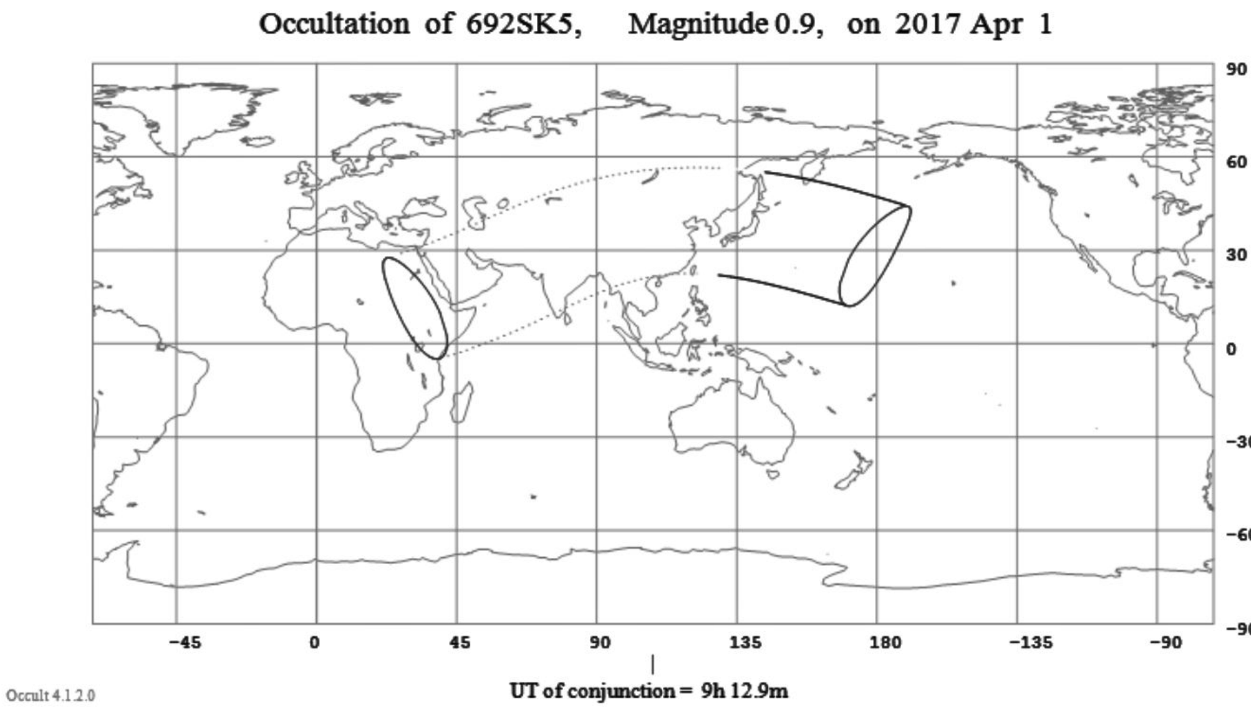
And speaking of photography, it’s easy to catch a bright pass of a satellite or station such as the ISS on camera. Shooting a satellite pass with a wide field is similar to shooting star trails; just leave the shutter open for 10-60 seconds using a tripod mounted camera. Modern DSLRs allow you to do several test exposures prior to the pass, to get the ISO, f/stop and shutter speed calibrated for local sky conditions.

You can even image the ISS through a telescope. Several sophisticated rigs exist to accurately track and image the space station through a scope, or you could use our decidedly low-tech but effective method of hand-guiding the telescope with the video running while the ISS passes overhead.

And that’s a brief overview of the exciting world of sat-spotting… let us know of your tales of triumph and tragedy as you sleuth out what’s going on overhead!

April 2017

Saturday, April 1st: The Moon occults Aldebaran



The footprint for the April 1st event. Image credit Occult 4.2.

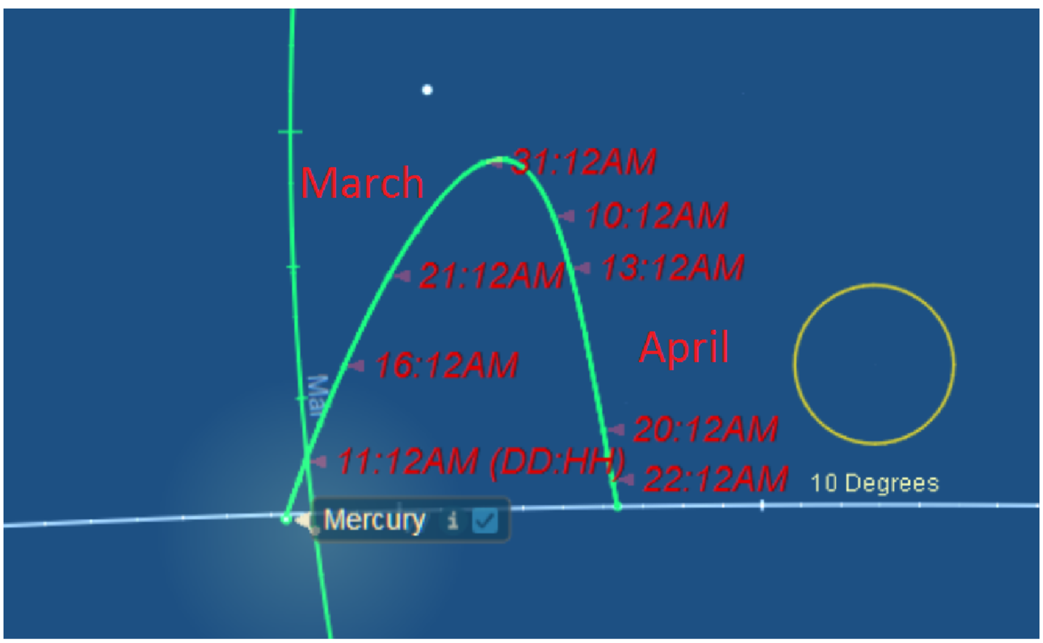
The 24% illuminated waxing crescent Moon occults the +0.9 magnitude star Aldebaran. The Moon is 4 days past New during the event. Both are located 58 degrees east of the Sun at the time of the event. The central time of conjunction is ~9:13 UT. The event occurs during the daylight hours over southern Asia, and under darkness for Japan, including the northwestern Pacific. The Moon will next occult Aldebaran on April 28th. This is occultation 29 in the current series of 49 for Aldebaran by the Moon running from January 29th, 2015 to September 3rd, 2018. This is the final observable occultation of Aldebaran by the Moon in the current cycle before the star passes into the morning sky

.

The view on April 1st. Image credit: Stellarium.

Many national flags include an idealized view of an occultation with the crescent Moon and a star, traditional in Islam. Several such examples include the flags of Turkey, Algeria and Pakistan.

Saturday, April 1st: Mercury at greatest elongation



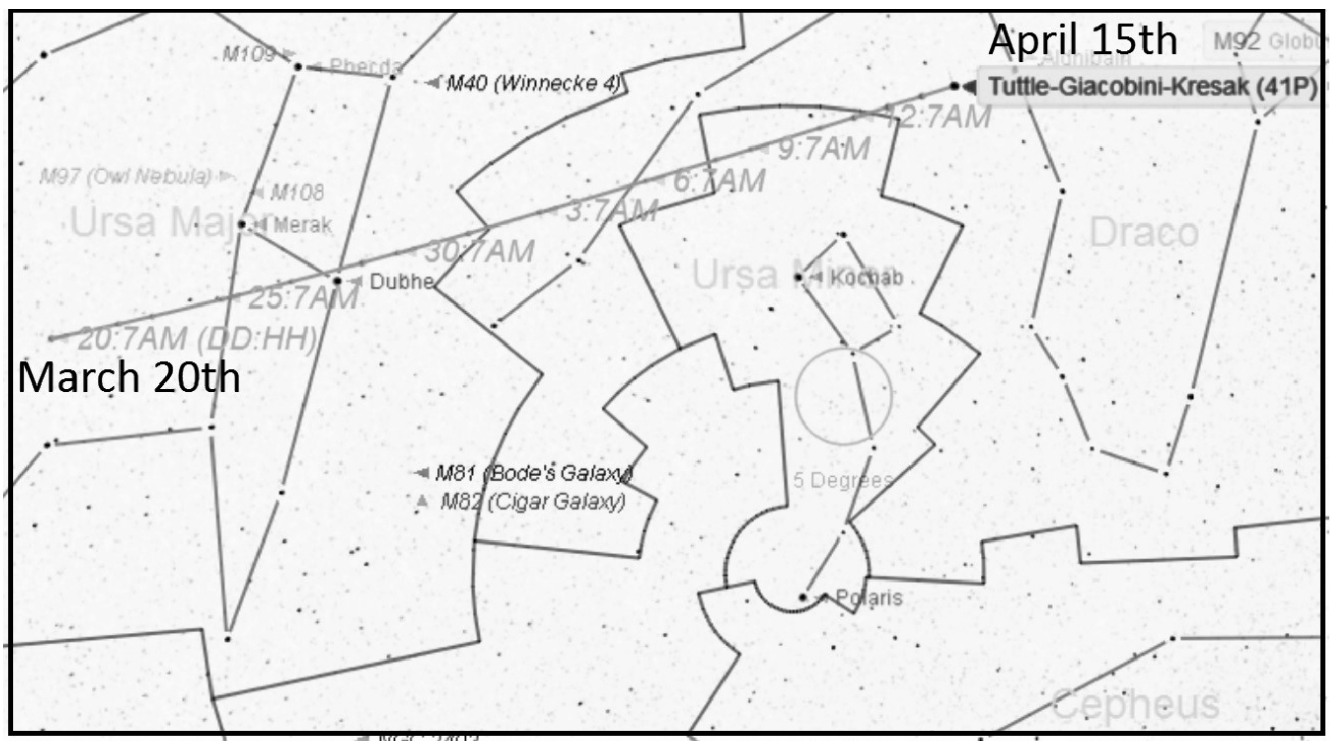
Looking west, the apparent path of Mercury through March and April.
Image credit: Starry Night Education Software.

The planet Mercury reaches greatest elongation 19 degrees east of the Sun in the dawn sky. The exact hour of greatest elongation occurs on April 1st at ~9:00 Universal Time (UT).

Mercury is 7.7” in apparent diameter and presents a 39% illuminated disk shining at magnitude +0.2 at greatest elongation. This is the **best evening apparition of Mercury for northern hemisphere viewers in 2017**. Mercury then begins to head back towards the Sun every evening until reaching inferior conjunction between the Sun and the Earth on April 20th, 2017. Mercury reaches theoretical dichotomy (half phase) on March 29th and a maximum brilliancy of -1.8 magnitude on March 7th. Mercury will next reach greatest western (dawn) elongation on May 17th. Favorable elongations for Mercury are a combination of seasonal ecliptic angle and perihelion and aphelion dates versus greatest elongation.

Mercury's orbit has an eccentricity of 0.2 (20%), and its perihelion precesses 1.5556 degrees relative to Earth per century. This movement was a mystery until the advent of Einstein's general theory of relativity, and relativity's explanation of the precession of the perihelion of the planet Mercury around the Sun stands as one of its great proofs.

Wednesday, April 5th Comet 41P/Tuttle-Giacobini-Kresák at its Brightest



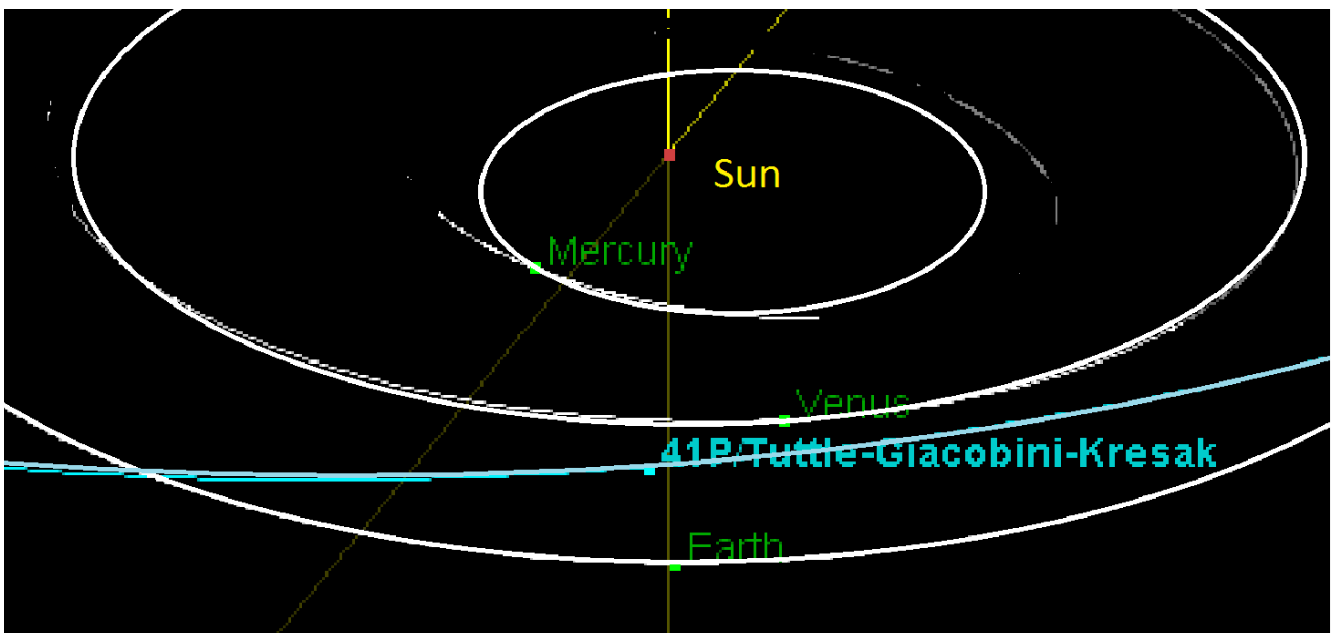
The path of Comet 41P/Tuttle-Giacobini-Kresák from March 20th to April 15th. Credit: Starry Night Education.

Comet 41P/Tuttle-Giacobini-Kresák is expected to reach maximum brightness around this date. Discovered by astronomer Horace Parnell Tuttle in 1858 and recovered by Michel Giacobini and L'ubor Kresák in 1907 and 1951, Comet 41P/Tuttle-Giacobini-Kresák orbits the

Sun once every 5.4 years on a short period orbit. Comet 41P/Tuttle-Giacobini-Kresák is set to break binocular +10th magnitude brightness on March 1st, and +6th magnitude (naked eye brightness) around April 5th. If an outburst occurs as on previous apparitions, it could reach a maximum brightness of magnitude +3 in early April.

Visibility prospects: At its brightest, Comet 41P/Tuttle-Giacobini-Kresák will pass through the constellations Ursa Major, Draco and Ursa Minor from March through April, and is best visible in the midnight sky 129 degrees east of the Sun at maximum brightness. This apparition favors the northern hemisphere. The comet reaches perihelion on April 11th, 2017 at 1.05 AU from the Sun, and the comet passes 0.15 AU from the Earth on April 5th, 13:30 UT. Some notable dates for Comet 41P/Tuttle-Giacobini-Kresák are:

March 28th – Passes near the bright +1.8 magnitude star Dubhe (Alpha Ursae Majoris).
April 7th – Reaches a declination of nearly 68 degrees north, passing just over 22 degrees from the north celestial pole.
April 17th – Passes near the bright +2.7 magnitude star Aldhiban (Eta Draconis).
April 25th – Passes near the bright +2.8 magnitude star Rastaban (Beta Draconis).
April 30th – Passes five degrees from the globular cluster M92.
Looking at the list of comets from late 2016, this may be the **brightest comet for 2017**.



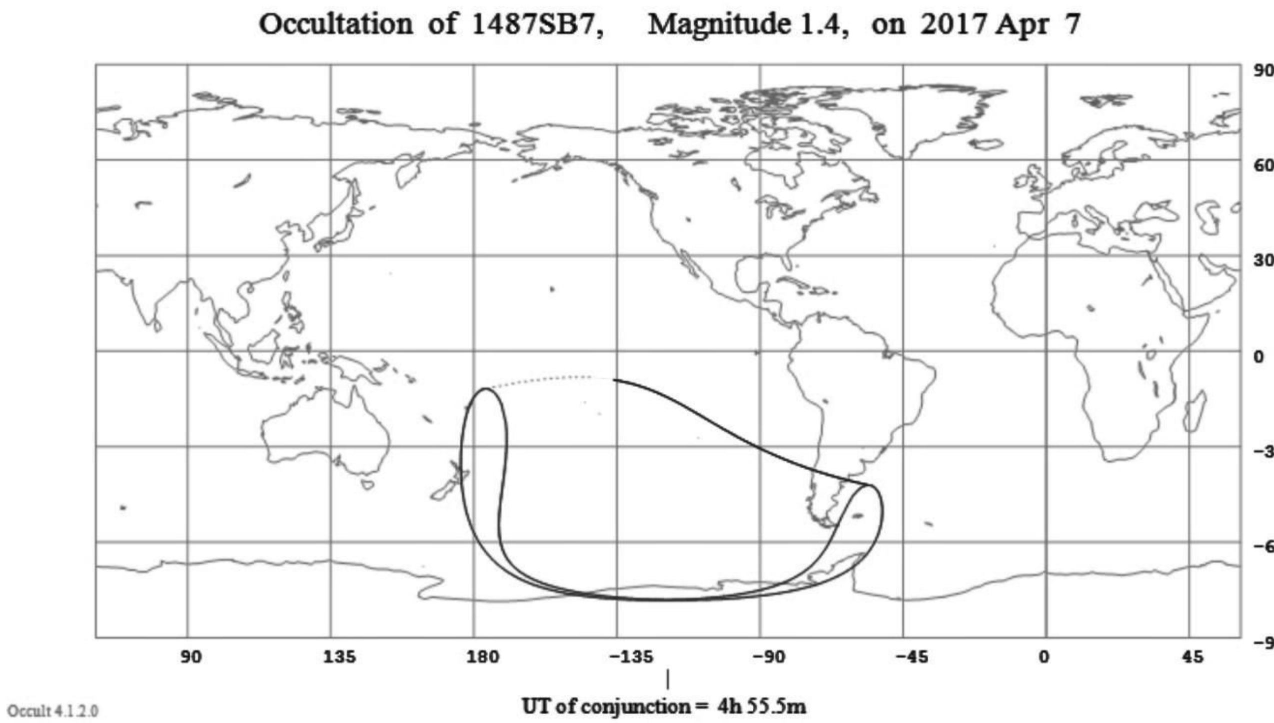
The April path of Comet 41P/Tuttle-Giacobini-Kresák. Credit: NASA/JPL.

This is the closest passage of Comet 41P/Tuttle-Giacobini-Kresák near Earth until January 20th , 2088.

Comets are designated 'P' for periodic if they have an orbit shorter than 200 years.

(comet pic)

Friday, April 7th: The Moon occults Regulus



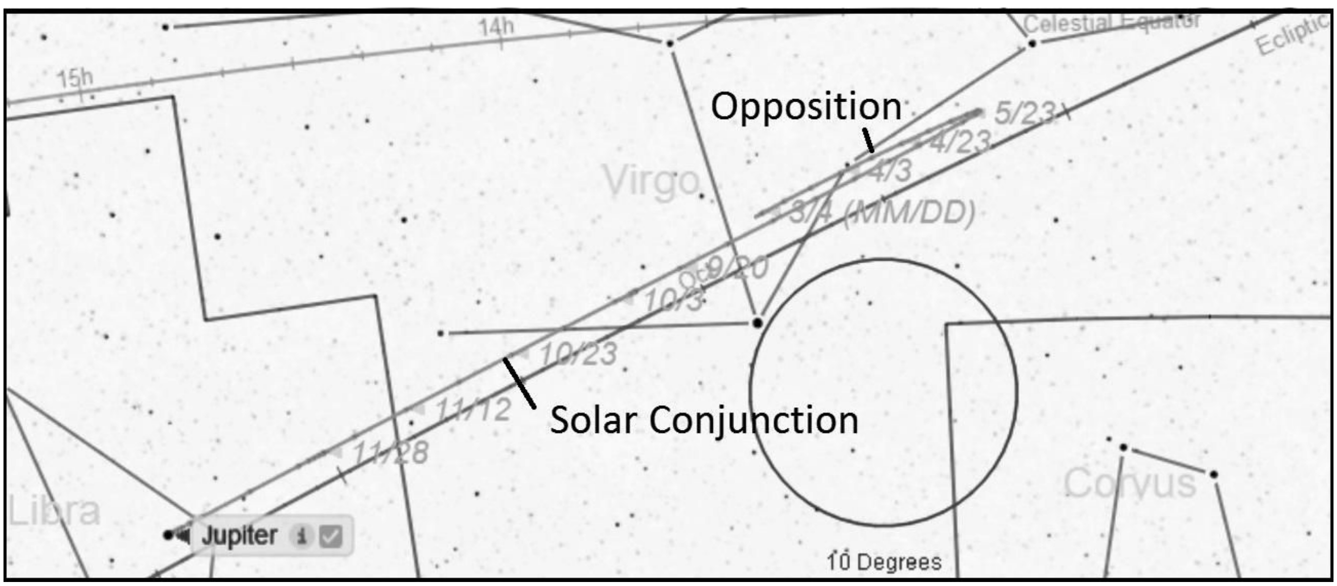
The footprint for the April 7th event. Image credit: Occult 4.2.

The 84% illuminated waxing gibbous Moon occults the +1.4 magnitude star Regulus. The Moon is 4 days from Full during the event. Both are located 132 degrees east of the Sun at the time of the event. The central time of conjunction is 4:56 Universal Time (UT). The event occurs during the daylight hours over the southern Pacific, and under darkness for the southern tip of South America, including Chile and Argentina. The Moon will next occult Regulus on May 4th, 2017. This is the 5th occultation in the current series of 19 running from December 18th, 2016 to April 24th, 2018. The rest of the world will see a close pass of the waxing gibbous Moon and the bright star.

The view on April 7th from Chile. Image credit: Stellarium.

Regulus was occulted by the planet Venus on July 7th, 1955. Venus will again occult Regulus later this century on October 1st, 2044.

Friday, April 7th: Jupiter reaches Opposition



The path of Jupiter through 2017. Image credit: Starry Night Education software.

The planet Jupiter reaches opposition for 2017 on April 7th at 21:00 Universal Time (UT). Opposition for 2017 occurs in the constellation Virgo. In 2017, Jupiter wanders along the ecliptic from Virgo to Libra. Oppositions for Jupiter occur every 13 months and mark the entrance of the planet into the evening sky about a month prior and are the prime season for imaging and observing the planet. The last opposition for Jupiter occurred on March 8th, 2016, and the next is May 9th, 2018. During opposition 2017, Jupiter shines at magnitude -2.5 and displays a disk 44” across. Jupiter is 667 million kilometers or 4.5 astronomical units (AU)

from the Earth during this year's opposition. With a declination of -5 degrees, this year's opposition only slightly favors the southern over the northern hemisphere in 2017. The shadows of Jupiter's four large moon (Io, Europa, Ganymede and Callisto) are cast straight back from our point of view at opposition, and can even disappear from view.

The planet Jupiter imaged by the Hubble Space Telescope. Credit: NASA/Hubble

The term 'opposition' means that a planet has reached an opposite point from the Sun in right ascension, and rises when the Sun sets.

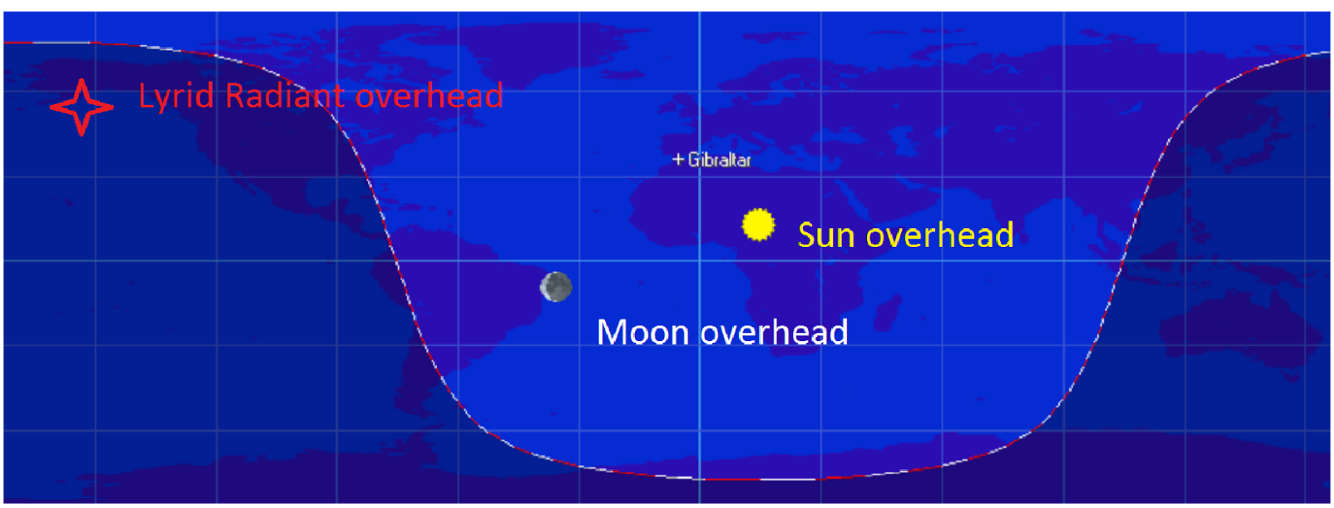
Saturday, April 22nd: The Lyrid Meteor Shower

The path of the Lyrid meteor shower radiant. Credit: Stellarium.

The Lyrid meteors are expected to peak on April 22nd at 12:00 Universal Time UT, favoring the western coast of North America. The shower is active for just over a week from April 16th to April 25th and can vary with a Zenithal Hourly Rate (ZHR) of up to 90 meteors per hour. In 2017, the Lyrids are expected to produce a maximum ideal ZHR of 18 meteors per hour. The radiant of the Lyrids is located at right ascension 18 hours 8 minutes, declination +32 degrees north at the time of the peak, in the constellation of Lyra.

The Moon is a 19% illuminated waning crescent at the peak of the Lyrids, making **2017 a favorable year** for this shower. In previous years, the Lyrids produced a ZHR=22 (2013) and a ZHR of 20 (2014).

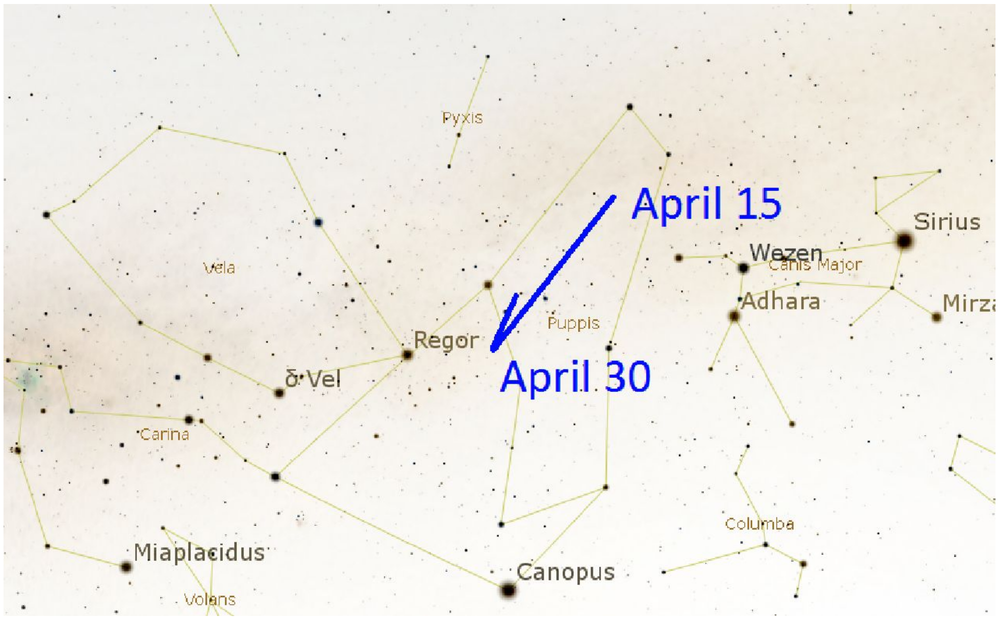
The Lyrid meteors strike the Earth at a moderate to fast velocity of 49 km/s, and produce few fireballs with an *r* = 2.1. The source of the Lyrids is C/1861 G1 Comet Thatcher.



The shower radiant, the Sun and Moon on April 22nd at 12 UT. Created using Orbitron.

Chinese astronomer Zuo Zhuan noted an outburst from the Lyrids in 687 BC.

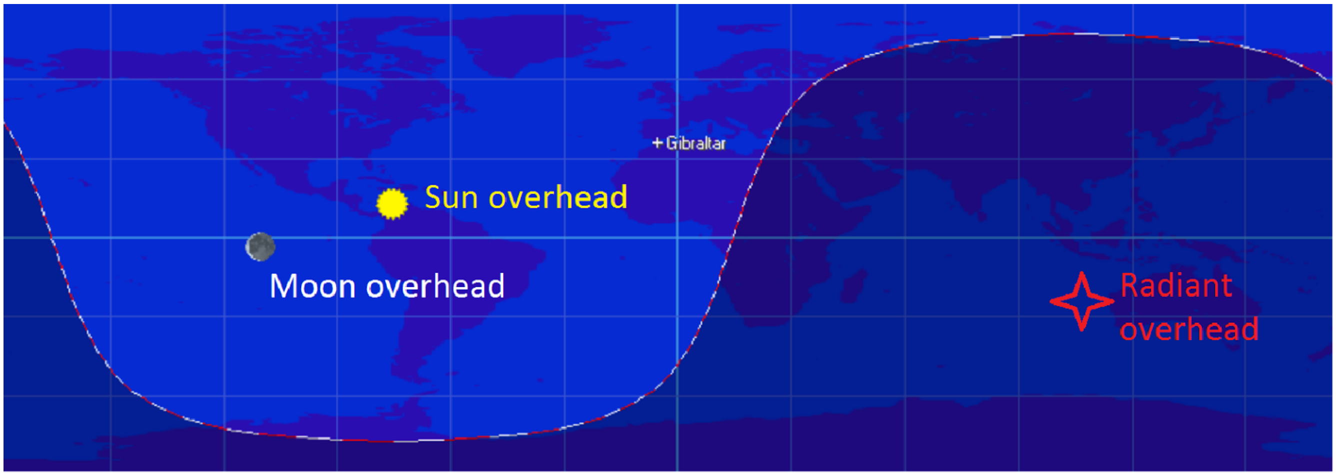
Sunday, April 23rd: The Phi Puppid Meteor Shower



The path of the Phi Puppid meteor shower radiant. (Credit: Stellarium)

The Phi Puppid meteors are expected to peak on April 23rd at 17:00 UT, favoring southeast Asia. The shower is active for a two week span from April 15th to April 22nd, and can vary with a Zenithal Hourly Rate (ZHR) of up to 40 meteors per hour. In 2017, the Phi Puppids are expected to produce a maximum ideal ZHR of 20 meteors per hour. The radiant of the Phi Puppids is located at right ascension 7 hours, 7 minutes, declination -45 degrees south at the time of the peak in the constellation of Puppis. The Moon is a 11% illuminated waning crescent at the peak of the Phi Puppids, making **2017 a favorable year** for this shower. In previous years, the Phi Puppids typically produced a variable ZHR.

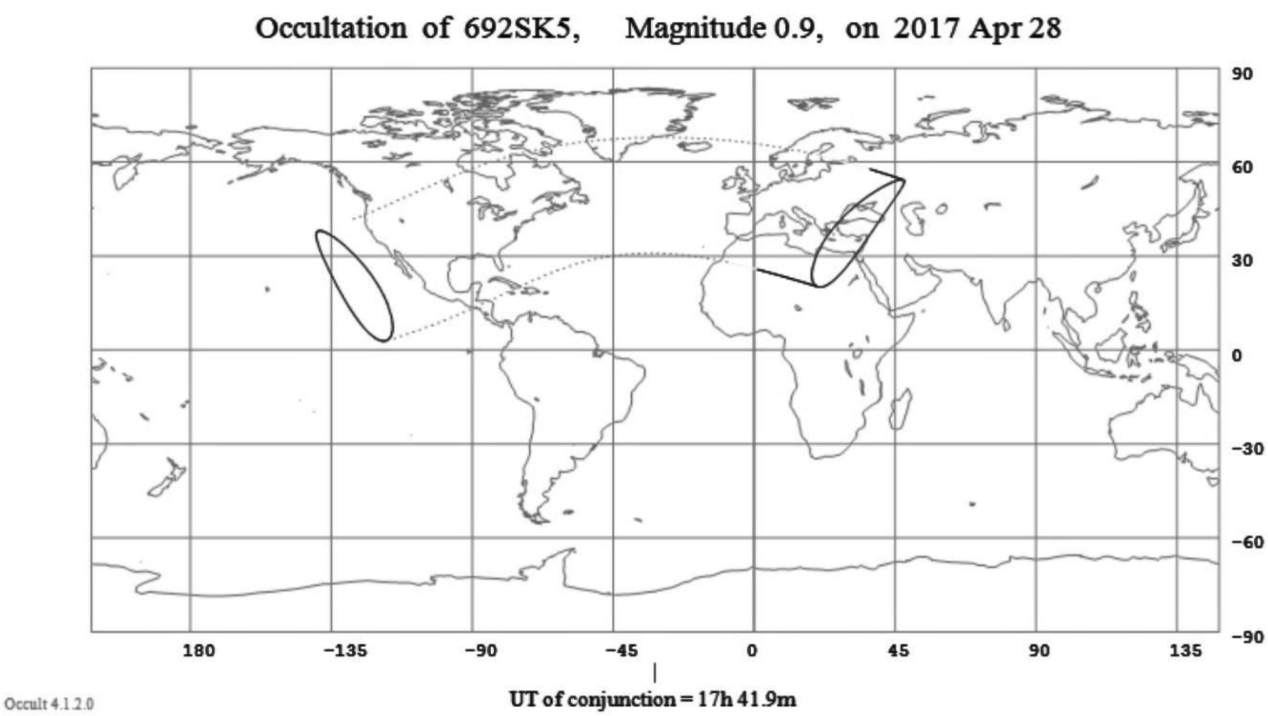
The Phi Puppids meteors strike the Earth at a moderate to fast velocity of 18 km/s, and produce few fireballs with an *r* value of 2. The source of the Phi Puppids is Comet 26P/Grigg-Skjellerup.



The shower radiant, the Sun and Moon on April 23 at 17 UT. Created using Orbitron.

The Phi Puppids produced notable outbursts when the host comet was near perihelion in 1977 and 1982. The comet again reaches perihelion in 2018.

Friday, April 28th: The Moon occults Aldebaran



The footprint for the April 28th event. Image credit: Occult 4.2.

The 7% illuminated waxing crescent Moon occults the +0.9 magnitude star Aldebaran. The Moon is 2 days past New during the event. Both are located 31 degrees east of the Sun at the time of the event. The central time of conjunction is 17:42 Universal Time (UT). The event

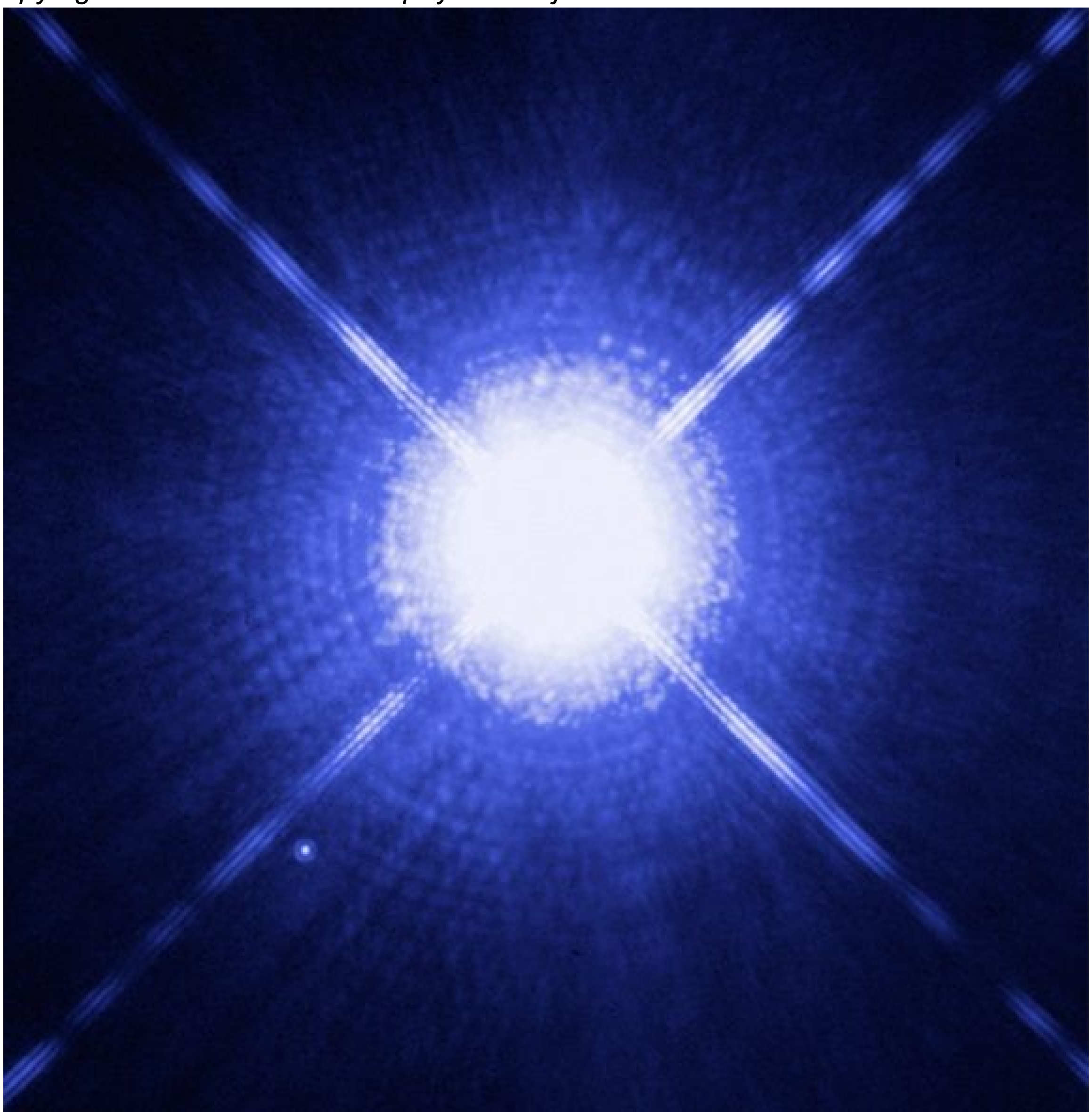
occurs during the daylight hours over North America and the UK, and under darkness for eastern Europe, including Turkey. The Moon will next occult Aldebaran on June 22nd. This is occultation 30 in the current series of 49 running from January 29th, 2015 to September 3rd, 2018. This is the last evening occultation of Aldebaran by the Moon for this cycle.

The view on April 28th. Image credit: Stellarium.

Aldebaran is visible near the Moon in the daytime, if you know exactly where to look using binoculars or a telescope.

April’s Challenge: 6 White Dwarf Stars for Backyard Telescopes

Spying a bizarre class of astrophysical objects



Sirius B. Image credit: NASA

Looking for something offbeat to observe? Some examples of curious astronomical objects lie within the reach of the dedicated amateur with a moderate-sized backyard telescope. With a little skill and persistence, you just might be able to track down a white dwarf star. Unlike splashy nebulae or globular clusters, a white dwarf star will just appear as a speck, a tiny dot in the field of view of your telescope’s eyepiece. But just as in the case of observing other exotic objects such as red giants and quasars, part of the thrill of tracking down these

astrophysical beasties is in knowing just *what* it is that you're seeing. Heck, many amateur astronomers fail to realize that any white dwarf stars are within range of their instruments and have never tracked one down.

The astrophysical nature of white dwarf stars was first uncovered in the early 20th century. Most of the early white dwarf stars discovered were companions in a binary star system and this allowed astronomers to gauge their mass by following the orbital motion of the pair over time. Soon, astronomers realized that they were looking at something peculiar, a new type of compact but massive stellar object that stubbornly refused to be pigeon-holed along the main sequence of the freshly conceived Hertzsprung-Russell diagram.

Today, we know that white dwarfs are the remnants of stars which have long since passed the red giant stage. We say that a white dwarf is a *degenerate star*, and no, this not a commentary on its moral state. The Chandrasekhar limit gives us an upper limit in size for a white dwarf at about 1.4 solar masses, beyond which electron degeneracy pressure can no longer act against the inward pull of gravity. Our Sun will one day become a white dwarf, over 6 billion years from now. Think of cramming the mass of our star into the volume of the Earth and you have some idea just how dense a white dwarf is: a cubic centimeter of white dwarf weighs 250 about tons, and two cup fulls of white dwarf would weigh more than a Nimitz-class aircraft carrier.

Think of a white dwarf as a cooling ember of a star long past its hydrogen fusing prime. White dwarfs will cool down to infrared-radiating black dwarfs over trillions of years, far longer than the present 13.7 billion year age of the universe. The age of white dwarfs currently observed is one on the underpinning tenets of modern Big Bang cosmology.

All amazing stuff. In any event, here is a baker's half dozen white dwarf stars that you can find with a telescope tonight. A more extensive list of the 30 nearest white dwarfs to the Earth can be found on Sol Station.

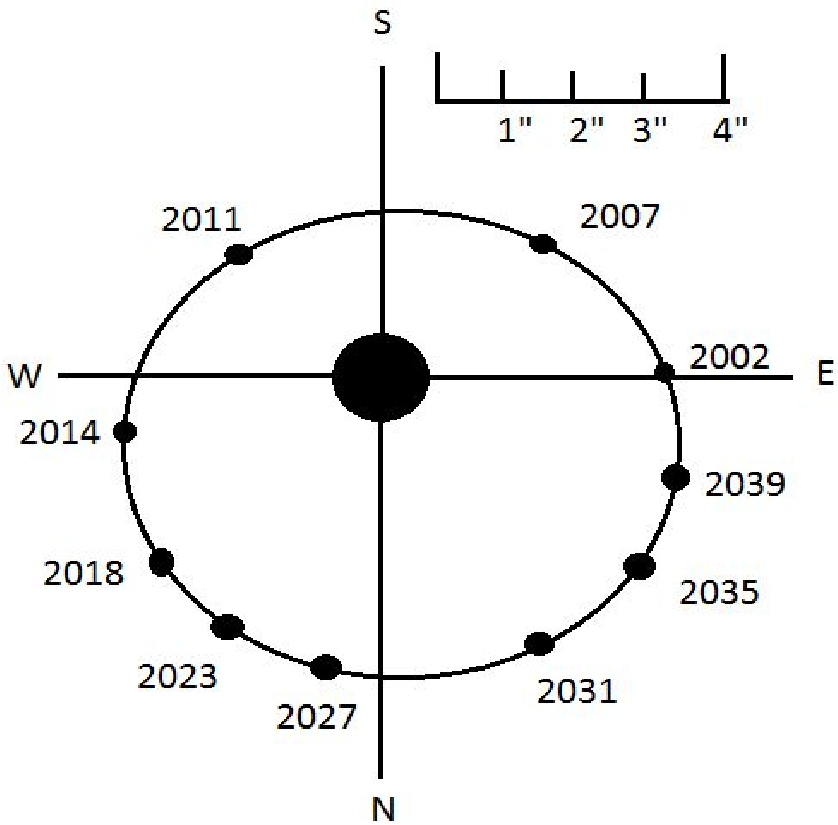
Sirius B: This is the nearest white dwarf to the Earth, at 8.6 light years distant. Shining at magnitude +8.5, Sirius B would be a cinch to see, if only dazzling Sirius A — the brightest star in our sky at magnitude -1.5 — were not nearby. Sirius B orbits its primary once every 50 years and will reach a maximum separation of 11.5" from its primary in 2025, a prime time to cross it off of your life list in the coming decade (See *Can You Spy Sirius B?* also in this book). Blocking the primary just out of the field of view or using an occulting bar eyepiece is key to finding Sirius B.

Sirius B was discovered by American telescope maker Alvan Graham Clark in 1862. The Dogon people of Mali also have some curious myths surrounding the star Sirius.

Constellation: Canis Major
Right Ascension: 6 Hours 45'
Declination: -16° 43'

Procyon B: Located 11.5 light years distant, Procyon B was discovered in 1896 by John Martin Schaeberle from the Lick observatory. Shining at magnitude +10.7, the chief difficultly with spotting this white dwarf, as with Sirius B, is that it has a companion about 10 magnitudes – that's 10,000 times brighter – nearby just 4.3" away.

Constellation: Canis Minor
Right Ascension: 7 hours 39'
Declination: +5° 13'



The orbit of Procyon B as seen from the Earth. Graphic created by the author.

-LP145-141: Also known as GJ 440, LP145-141 is one of the best southern hemisphere white dwarf stars on the list. LP145-141 is a solitary white dwarf shining at magnitude +11.5. Located 15 light years distant, LP145-141 is thought to be a member of the nearby Wolf 219 Moving Group of stars.

Constellation: Musca
Right Ascension: 11 Hours 46'
Declination: -64° 50'

-Van Maanen's Star: Shining at magnitude +12.4 and located 14.1 light years distant, Van Maanen's star is the closest solitary white dwarf to Earth and the best example of a white dwarf for small telescopes. Discovered by Ariaan van Maanen in 1917, Van Maanen's Star also has a very high proper motion of 3" per year.

Constellation: Pisces
Right Ascension: 00 Hours 49’
Declination: 05° 23’

-40 Omicron Eridani B: This is a great one to track down. The triple system of 40 Omicron Eridani b contains a fine example of a red and white dwarf orbiting a main sequence star. Located 16.5 light years distant and shining at magnitude +9.5, Omicron Eridani was the first white dwarf star discovered in 1783 by Sir William Herschel, although its true nature wasn’t deduced until 1910. Omicron Eridani B is currently 82” from its primary, an easy split.

Constellation: Eridanus
Right Ascension: 4 Hours 15’
Declination: 7° 39’

-Stein 2051: Rounding off the list and located just over 18 light years distant, Stein 2051 is another example of a red dwarf/white dwarf pair. Stein 2051 b shines at a similar brightest to Van Maanen’s star at magnitude +12.4.

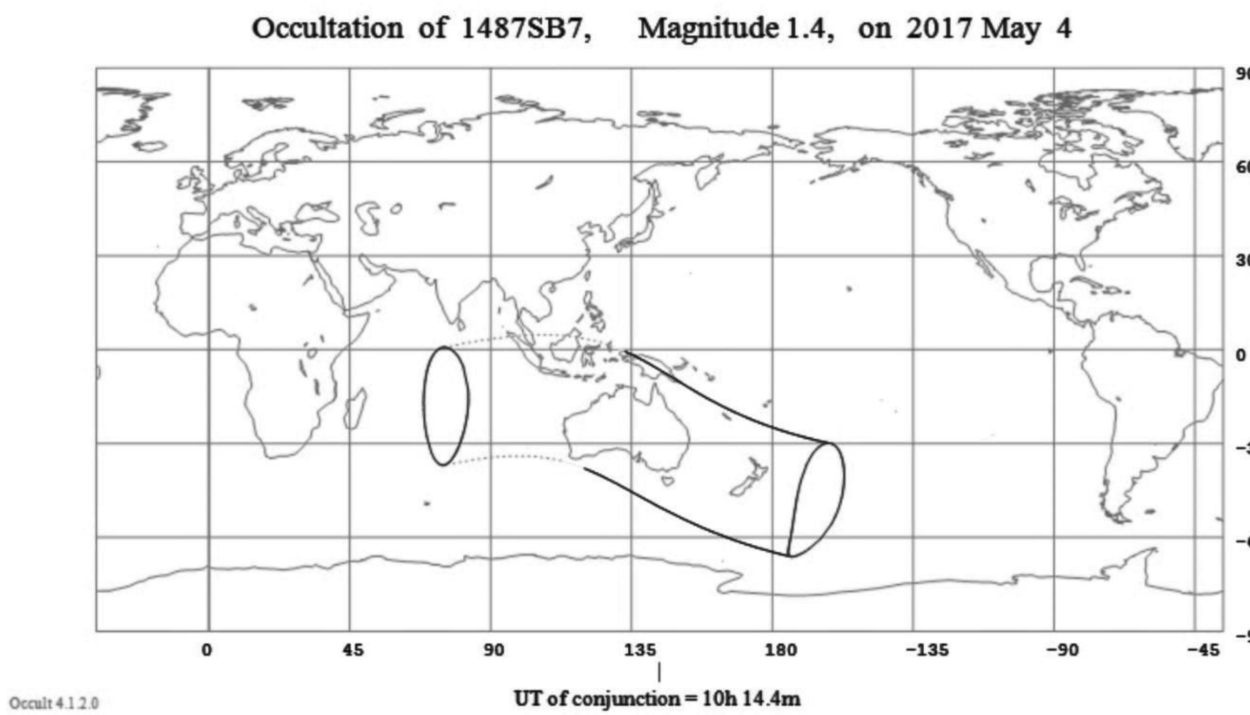
Constellation: Camelopardalis
Right Ascension: 4 Hours 31’
Declination: +58° 59’

Let us know about your trials and triumphs in hunting down these fascinating objects!

Originally published on Universe Today.

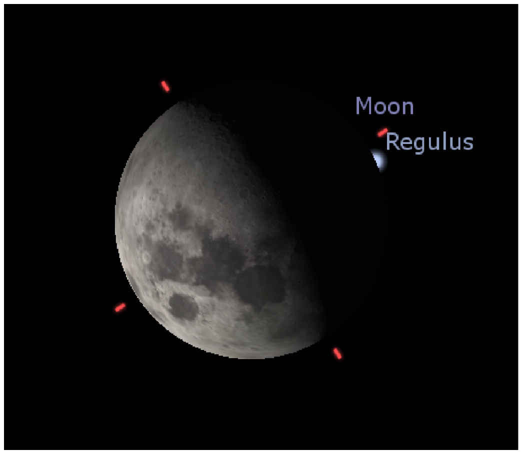
May 2017

Thursday, May 4th: The Moon occults Regulus



The foot print for the May 4th event. Image credit: Occult 4.2.

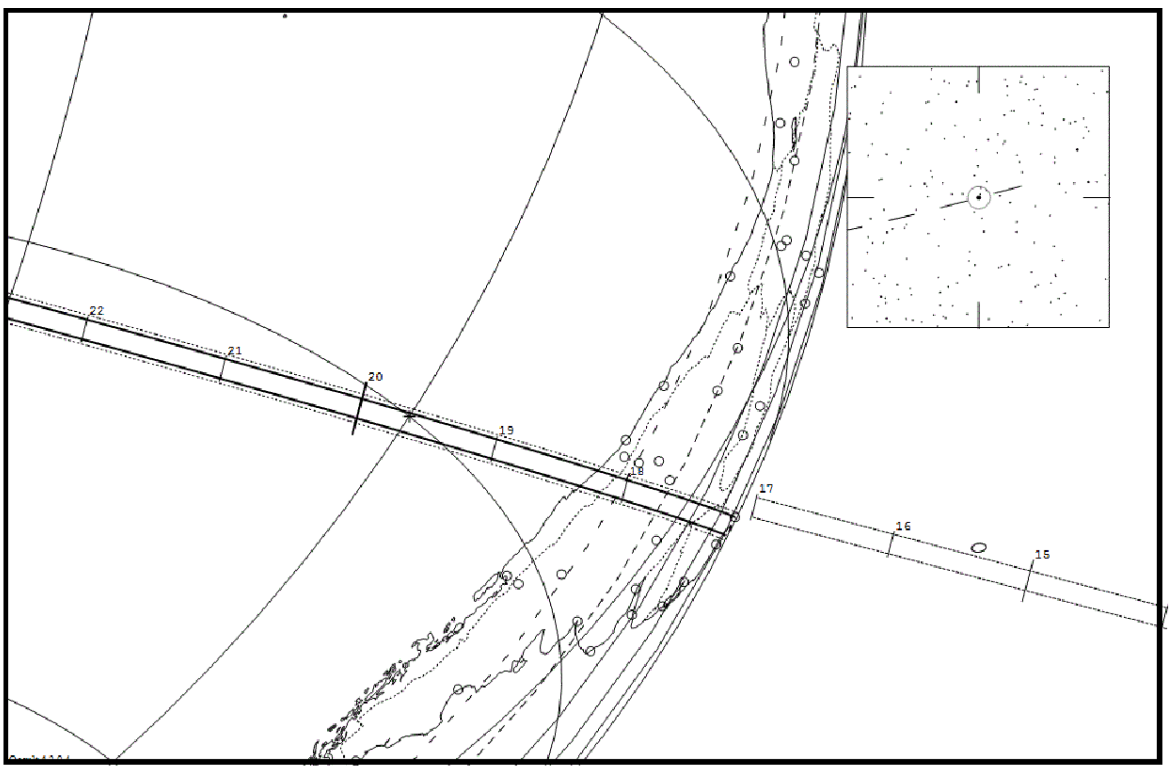
The 64% illuminated waxing gibbous Moon occults the +1.4 magnitude star Regulus. The Moon is six days prior to Full during the event. Both are located 106 degrees east of the Sun at the time of the event. The central time of conjunction is 10:14 Universal Time (UT). The event occurs during daylight hours over Indonesia, and under darkness for Australia and New Zealand. The Moon will next occult Regulus again this month on May 31st. This is the 6th occultation in the current series of 19 running from December 18th, 2016 to April 24th, 2018. This is the best placed occultation of Regulus by the Moon for Australia and New Zealand for 2017, and indeed, for the entire cycle.



The view on May 4th from Australia. Image credit: Stellarium.

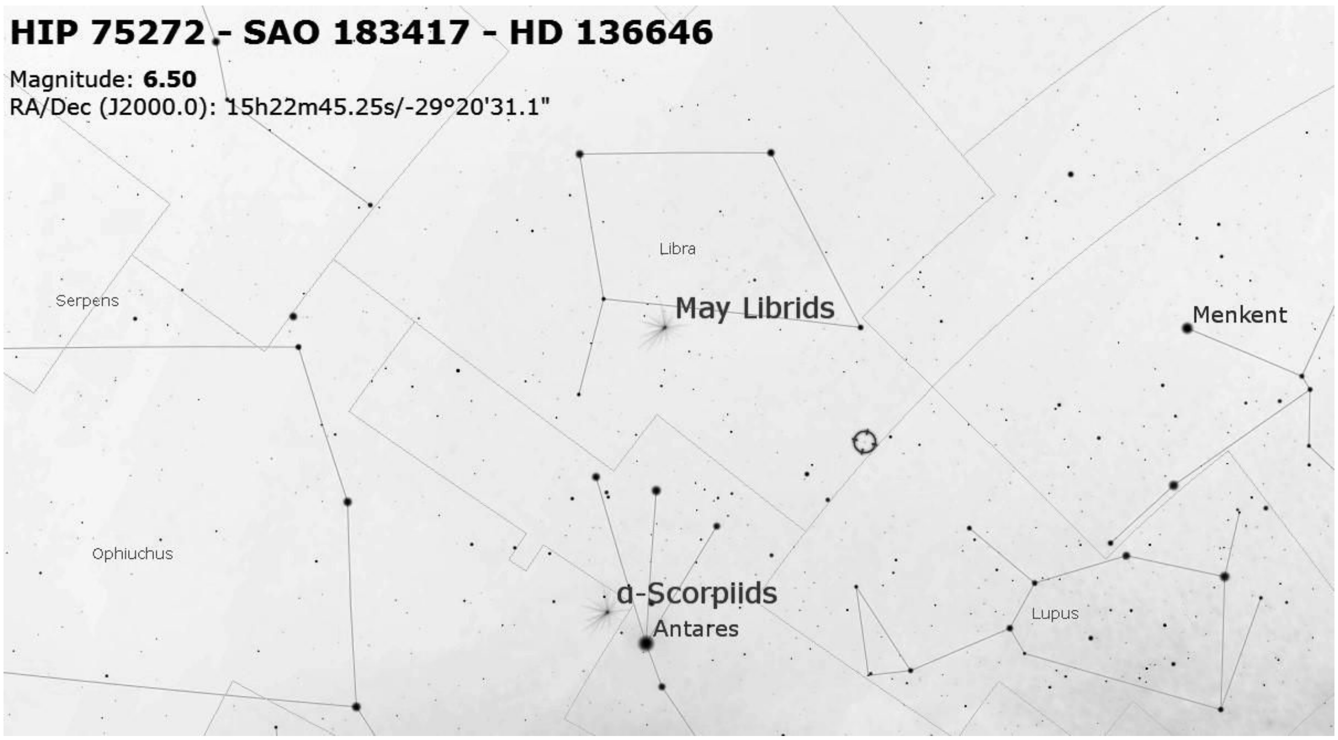
Located 77 light years distant, the Regulus system has at least four components: a B/C pair shining at a combined magnitude of +8 with an apparent separation of 3”, (5,000 AU physical distance in a ~600 year orbit) and an unseen white dwarf companion in a tight 40 day orbit.

Thursday, May 4th: Asteroid 407 Arachne occults a Bright Star



The occultation path over South America. Image credit: Occult 4.2.

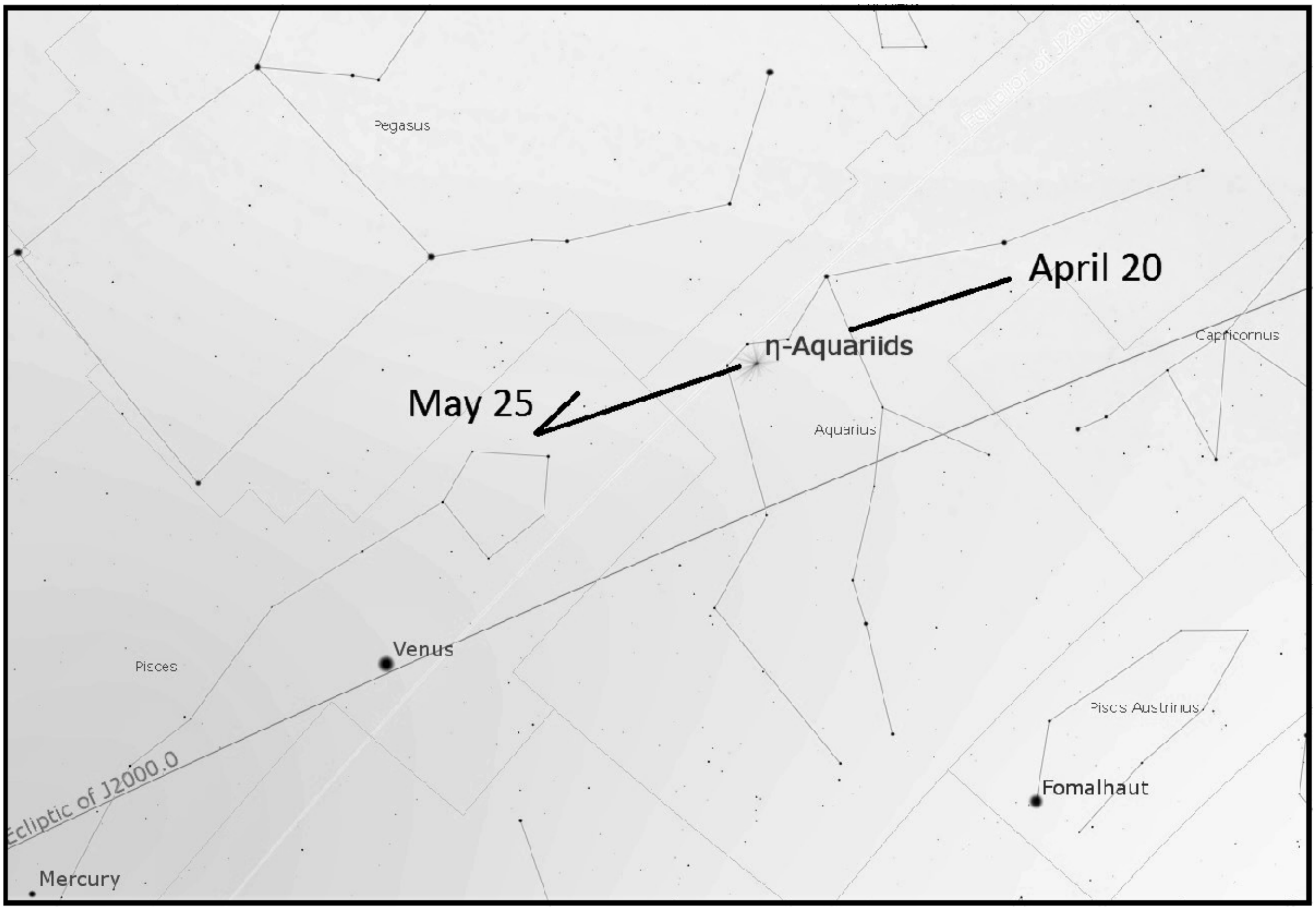
Asteroid 407 Arachne occults the +6.5 star HIP 75272. The 100 kilometer wide path crosses the Earth from 10:17 to 10:35 Universal Time (UT). The occultation path crosses South America around 4:18 UT, including Argentina and Chile. The asteroid's brightness is +12.8 magnitude at the time of the event, and the occultation should last 8.5 seconds at maximum duration as seen from the center line. The probability rank for this event is 99%. The Moon is 64% waxing gibbous during the event. The occulted star is located in the constellation Libra. As seen from Central Chile, the occultation occurs under darkness and is 15 degrees above the horizon. Solar elongation for the occultation is 164 degrees, and the maximum expected magnitude drop is 6.3.



Finder Chart for the location of the occultation in Libra. Credit: Stellarium.

About 95 kilometers in diameter, 407 Arachne orbits the Sun once every 4.3 years. The asteroid was discovered by Max Wolf on October 13th, 1895 observing from the Mannheim Observatory in Heidelberg. Wolf pioneered the use of astrophotography to discover asteroids, claiming 248.

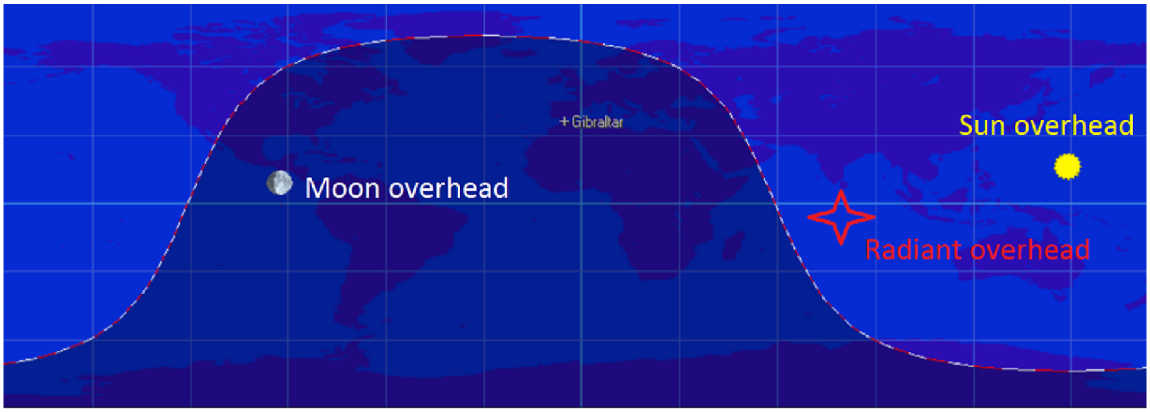
Saturday, May 6th: The Eta Aquarid Meteor Shower



The path of the Eta meteor shower radiant. Credit: Stellarium.

The Eta Aquarid meteors are expected to peak on May 6th at ~2:00 UT, favoring eastern Africa. The shower is active for over a month from April 19th to May 28th, and can vary with a Zenithal Hourly Rate (ZHR) of 40-85 meteors per hour. In 2017, the Eta Aquarids are expected to produce a maximum ideal ZHR of 50 meteors per hour.

The radiant of the Eta Aquarids is located at Right Ascension 22 Hours 20 minutes, Declination -1 degree south at the time of the peak, in the constellation of Aquarius.



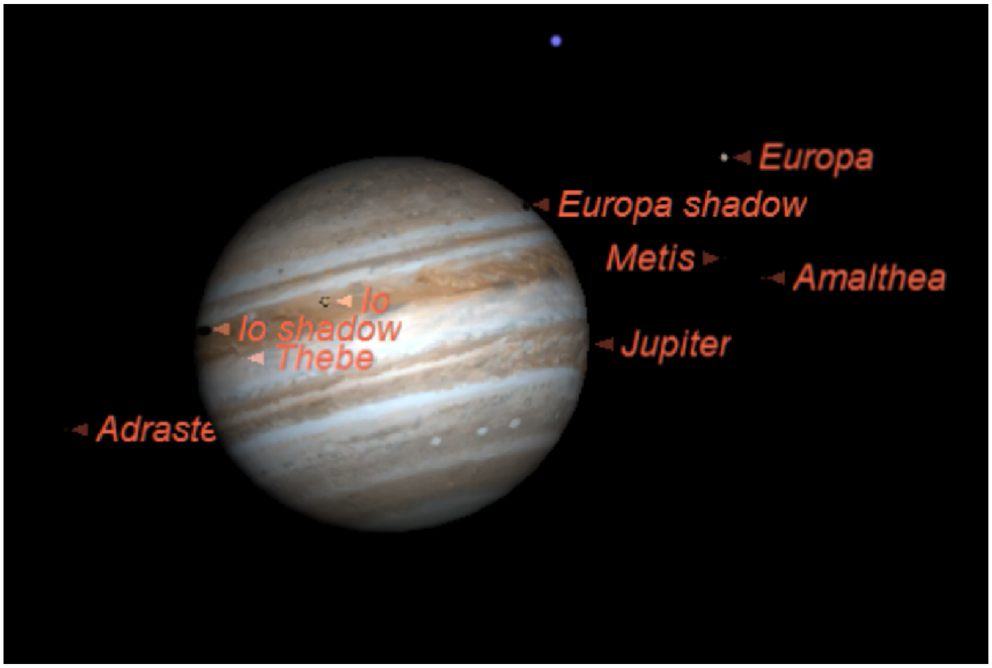
The radiant vs the Sun, Moon & Earth's shadow on May 6 at 2:00 UT. Created using Orbitron.

The Moon is a 82% illuminated waxing gibbous at the peak of the Eta Aquarids, making **2017 an unfavorable year** for this shower. In previous years, the Eta Aquarids produced a ZHR=53 (2014) and a ZHR of 135 (2013). The Eta Aquarids meteors strike the Earth at a moderate/fast velocity of 66 km/s, and produce many fireballs with an *r* = 2.4. The source of the Eta Aquarids is comet 1/P Halley.

The Eta Aquarids are one of two annual meteor showers from Comet Halley, the other being the October Orionids.

Meteor shower, credit: NASA

Friday, May 12th: Io and Europa Shadow Transit Season



Io & Europa casting shadows: the scene at 2:00 UT on May 12th. Image credit: Starry Night.

Io and Europa double shadow transit season begins. This series of simultaneous transits runs from May 12th to June 23rd, and includes 13 events. This is the longest season of double shadow transits for 2017.

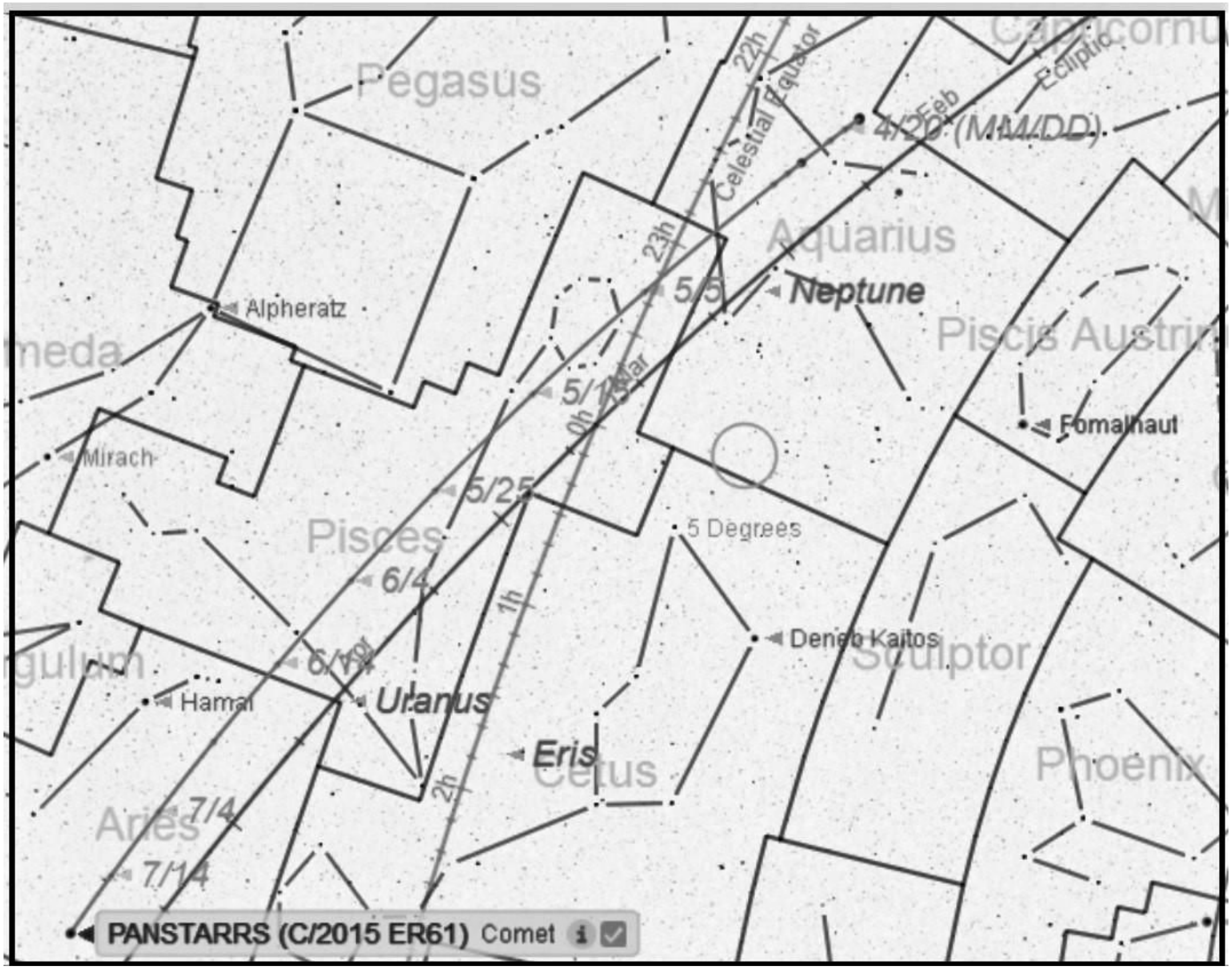
Simultaneous Shadow transits of Io and Europa

Date	Solar elongation	Duration	Begins	Ends	Region Favored
May 12th	143 deg E	11 minutes	1:57 UT	2:08 UT	South America/E. North America
May 15th	139 deg E	33 minutes	14:54 UT	15:27 UT	East Asia/Australia
May 19th	135 deg E	53 minutes	3:52 UT	4:45 UT	Western North America
May 22nd	132 deg E	75 minutes	16:48 UT	18:03 UT	India, Mideast and Eastern Africa
May	128 deg E	96	5:46 UT	7:22 UT	The central Pacific Ocean

26th		minutes			
May 29th	125 deg E	118 minutes	18:43 UT	20:41 UT	Africa/Eastern Europe
June 2nd	121 deg E	136 minutes	7:39 UT	9:55 UT	W Pacific/E Australia/New Zealand
June 5th	118 deg E	127 minutes	20:45 UT	22:52 UT	W. Europe/Africa/E South America
June 9th	114 deg E	105 minutes	10:04 UT	11:49 UT	Australia/Japan
June 12th	111 deg E	83 minutes	23:23 UT	00:46 UT	South America
June 16th	108 deg E	62 minutes	12:42 UT	13:44 UT	Southeast Asia
June 20th	104 deg E	41 minutes	2:01 UT	2:42 UT	United States, Mexico
June 23rd	101 deg E	19 minutes	15:19 UT	15:38 UT	Indian subcontinent

Jupiter's moons Io, Europa and Ganymede are locked in a 1:2:4 orbital resonance, making such cycles of double shadow transits possible.

Monday, May 15th: Comet C/2015 ER61 PanSTARRS at its Brightest



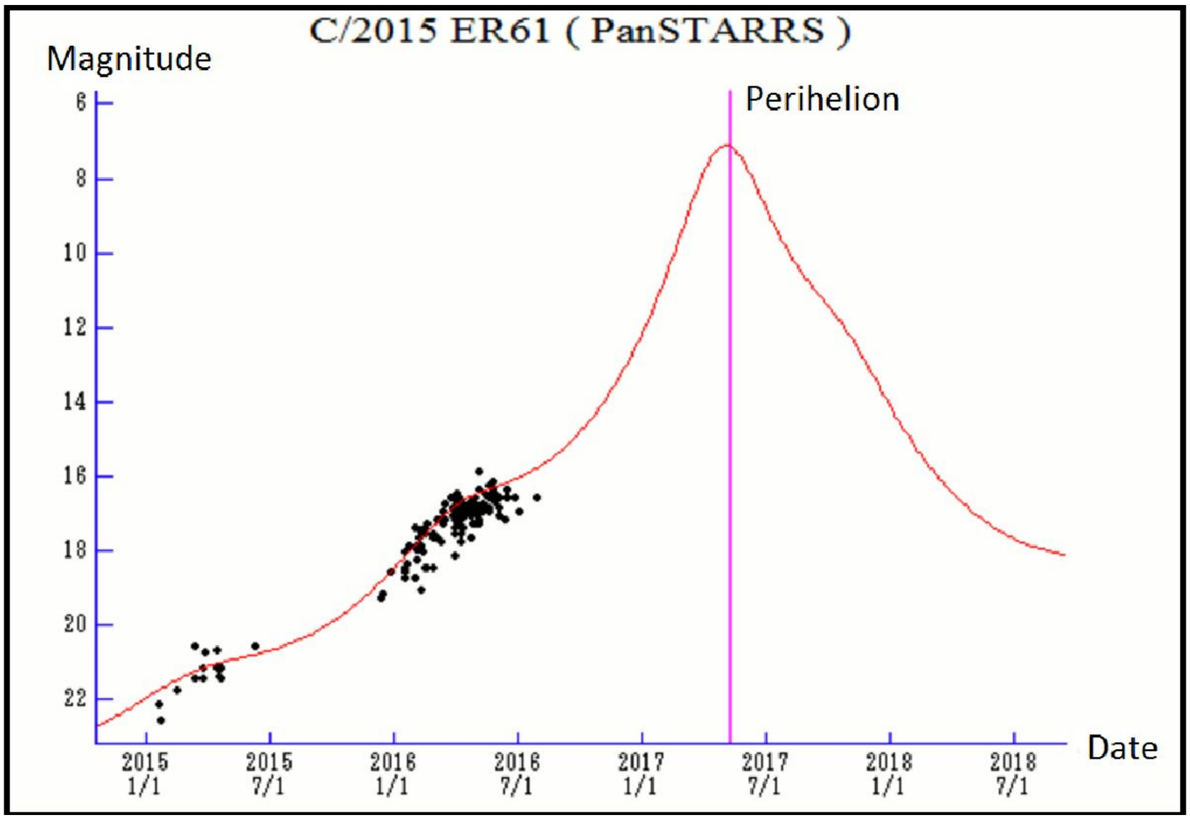
The path of C/2015 ER61 PanSTARRS from mid-April to mid-July. Credit: Starry Night.

Comet C/2015 ER61 PanSTARRS is expected to reach maximum brightness around this date. Discovered by the automated PanSTARRS1 survey on March 14th, 2015, Comet ER61 PanSTARRS orbits the Sun once every 43,000 years on a long period orbit. Comet ER61 PanSTARRS is set to break binocular +10th magnitude brightness in January 2017, and reach a maximum of +7th magnitude, just shy of naked eye brightness in mid-May.

Visibility prospects: At its brightest, comet C/2015 ER61 PanSTARRS will pass through constellations Aquarius, Pisces and Aries from April 19th to July 31st and is best visible in the dawn sky 53 degrees west of the Sun at maximum brightness. This apparition favors both the northern and southern hemisphere. Its perihelion on May 10th, 2017 is 1.04 AU from the Sun, and the comet passes 1.08 AU from the Earth on April 4th, 2017. The comet passes several

notable deep sky objects as it crosses the galactic equator on February 27th, including between M20 and M8 on February 28th, M22 on March 28th, and M72, M73 and NGC7009 on April 7th. The comet crosses the celestial equator northward on May 4th, and very near M74 on June 13th. The waning crescent Moon also passes one degree from the comet on March 22nd.

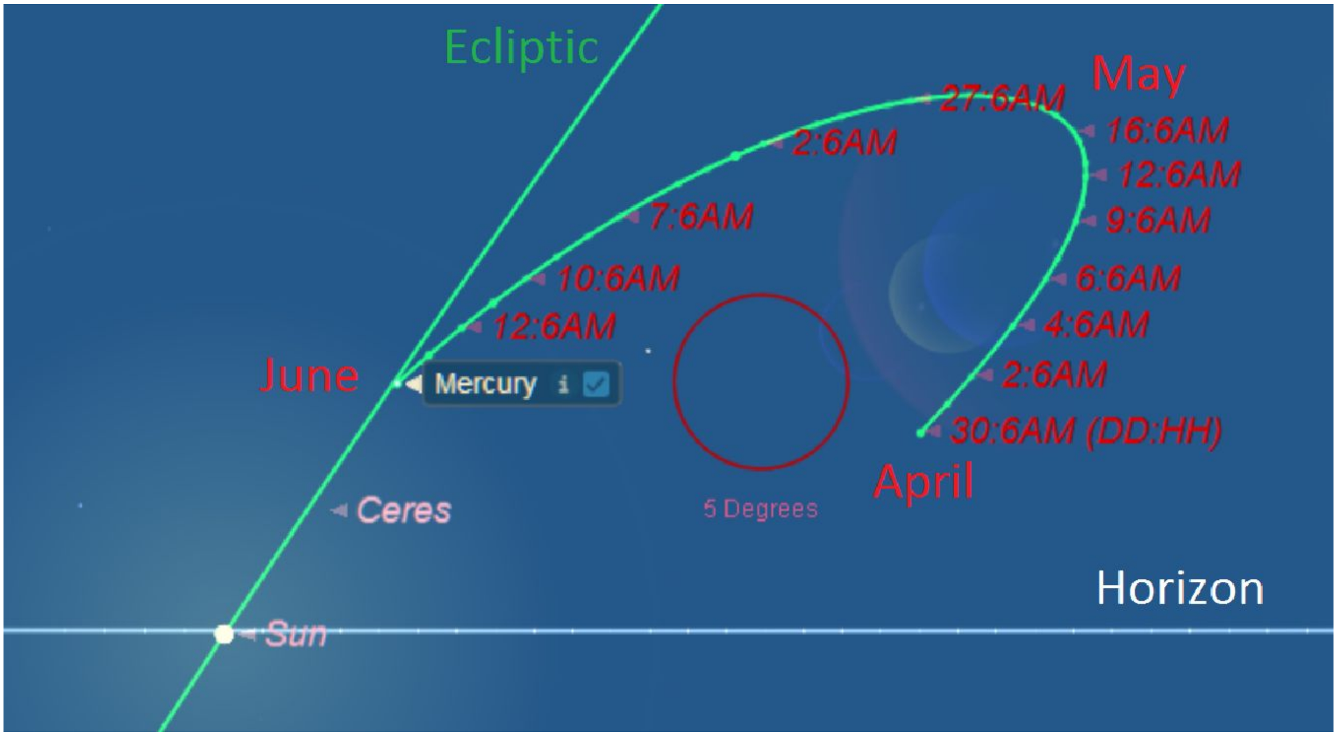
Initially classified as an asteroid, Comet C/2015 ER61 has the fourth most distant aphelion of any known solar system object at around 2,450 AU distant. A close 0.9 AU passage by Jupiter on March 28, 2016 shorted its aphelion to 854 AU.



The projected light curve for Comet C/2015 ER61 PanSTARRS with observations (black dots) as of September 2016. Credit: Seiichi Yoshida, *Weekly Information About Bright Comets*.

A given comet entering the inner solar system for the first time stands a 40% of having its orbit altered by Jupiter.

Thursday, May 18th: Mercury at Greatest Elongation



Looking east, April 30th – June 14th. Image credit: Starry Night Education Software.

The planet Mercury reaches greatest elongation 26 degrees west of the Sun in the dawn sky. The exact hour of greatest elongation occurs on May 18th at ~1:00 Universal Time (UT). Mercury is 8.3” in apparent diameter and presents a 41% illuminated disk at greatest elongation. This morning apparition of Mercury favors viewers in the southern hemisphere. Mercury then begins to head back towards the Sun every evening until reaching superior conjunction on the far side of the Sun and the Earth on June 21st. Mercury reaches theoretical dichotomy (half phase) on May 24th and a shines at a brilliancy of +1.4 magnitude at greatest elongation. Mercury will next reach greatest eastern (dusk) elongation on July 30th. Mercury reached aphelion 0.47 AU from the Sun on May 6th.

On March 27th, 1974, spurious readings from the Mariner 10 spacecraft were temporarily interpreted by NASA engineers as a possible moon orbiting Mercury.

Friday, May 26th: The Closest Lunar Perigee of the Year

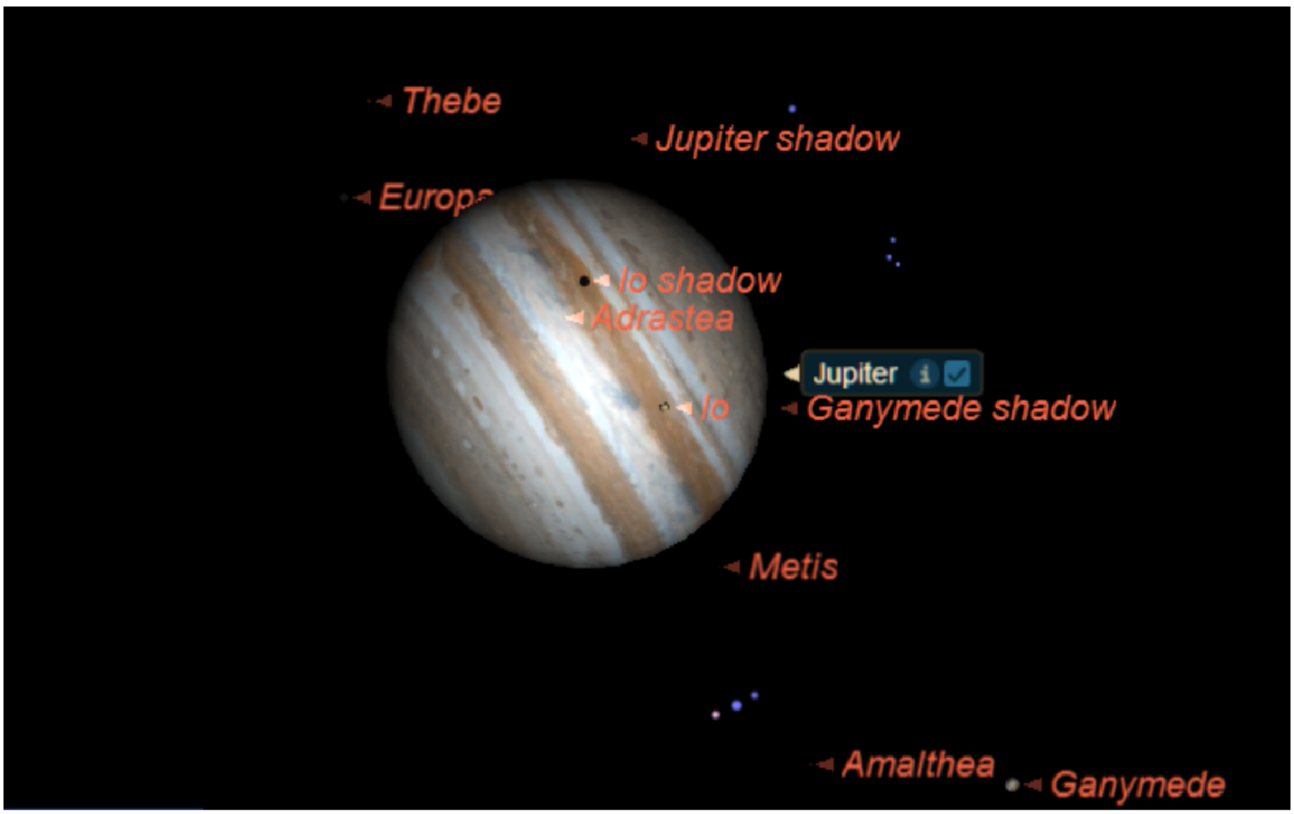
Waxing Moon by Paul Stewart. https://upsidedownastronomer.wordpress.com/

The Moon reaches its closest perigee of 2017. The moment of perigee occurs at 1:24 Universal Time (UT), during which the Moon will reach its closest approach to the Earth, appearing at the zenith (directly overhead) for the Hawaiian Islands. The Moon is waxing crescent, 1% illuminated, in the astronomical constellation of Taurus at perigee. This occurs just 5 hours and 38 minutes past New on May 25th. The Moon reaches perigee 13 times in 2017, ranging from 357,209 kilometers (closest on May 26th) to 369,855 kilometers on September 13th. The Moon appears 33' 34” across at perigee, versus the typical appearance of 29' 30” across at apogee. The closest perigee for the 21st century is 356,425 kilometers on

December 6th, 2052, and the most distant perigee for the century is 370,356 kilometers distant on January 3rd, 2100.

The time it takes the Moon to return to a similar node where its orbit intersects the ecliptic plane (i.e., ascending or descending node and then returning) is 27.2 days, known as a *draconic* or *draconitic month*. This cycle is useful in the calculation of lunar and solar eclipses.

Sunday May 28th: Io-Ganymede Shadow Transit Season Begins



Io and Ganymede both cast shadows on Jupiter: the scene at 00:45 UT. Image credit: Starry Night.

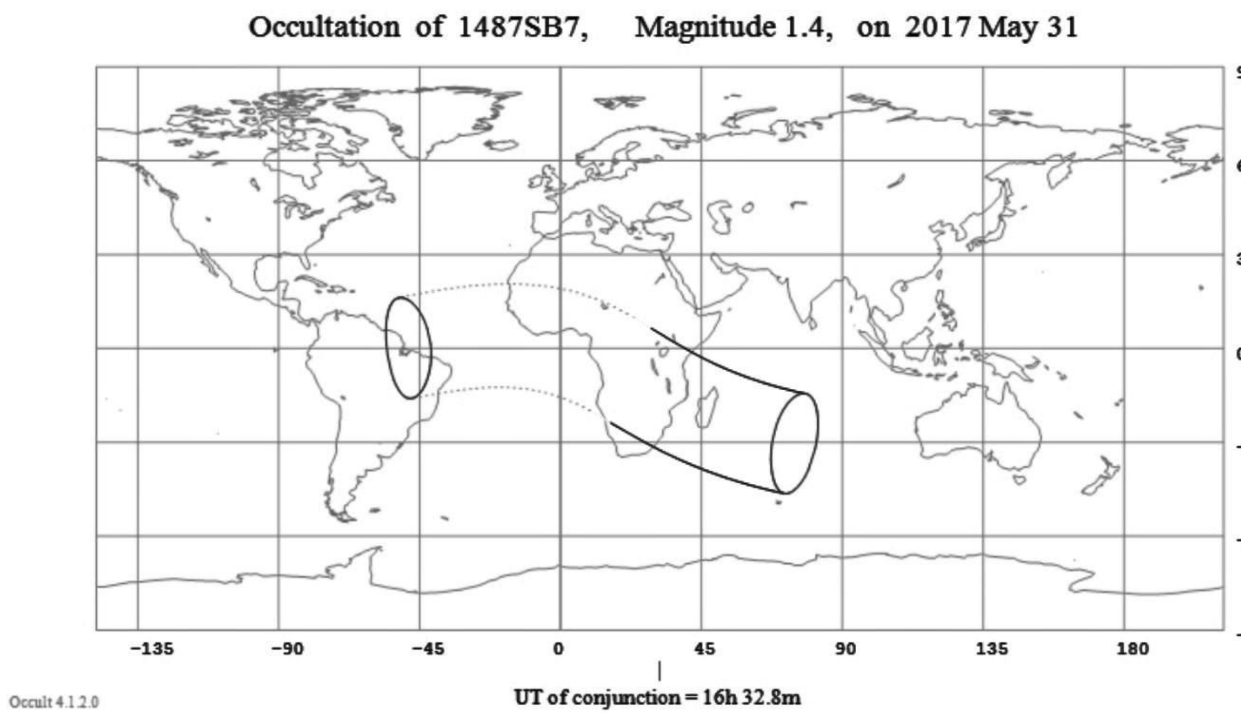
Io and Ganymede double shadow transit season begins. This series of simultaneous transits runs from May 28th to June 4th, and includes 2 events. The waxing gibbous Moon lies very near (1.5 degrees) north of Jupiter during the June 4th event.

Simultaneous Shadow transits of Io and Ganymede					
Date	Solar elongation	Time	Begins	Ends	Region Favored

May 28th	127 deg E	36 minutes	00:14 UT	00:50 UT	SE US, Brazil
June 4th	119 deg E	131 minutes	2:12 UT	04:23 UT	S. America/E. North America

A triple shadow transit of Jupiter's large moons must involve Callisto, the only moon whose shadow can occasionally 'miss' Jupiter (as it does in 2017) as seen from the Earth.

Wednesday, May 31st: The Moon occults Regulus



The footprint for the May 31st event. Image credit Occult 4.2.

The 41% illuminated waxing crescent Moon occults the +1.4 magnitude star Regulus. The Moon is six days past New during the event. Both are located 79 degrees east of the Sun at the time of the event. The central time of conjunction is 16:33 Universal Time (UT). The event occurs during the daylight hours over western Africa, and under darkness for southeastern Africa, including Madagascar. The Moon will next occult Regulus on June 28th. This is the 7th occultation of 19 in the current series for Regulus running from December 18th, 2016 to Apr 24th, 2018. This is the most central occultation of a bright star by the Moon for 2017, and also the most central occultation of Regulus in the current cycle.

The view on May 31st from Madagascar. Image credit: Stellarium.

Sometimes referred to as “The Lion's Heart,” the name Regulus is Latin for “The Little King.”

May’s Challenge: Scouting out Moons of the Solar System

How to see and go beyond the standard bright moons of the solar system.

Saturn's moons Titan, Mimas and Rhea. Image credit: NASA/Cassini/Caltech Space Science Institute.

Like splitting double stars, hunting for the faint lesser known moons of the solar system offers a supreme challenge for the visual observer.

Sure, you’ve seen the Jovian moons do their dance, and Titan is old friend to many a star party patron as they check out the rings of Saturn… but have you ever spotted Triton or Amalthea?

Welcome to the challenging world of moon-spotting. Discovering these moons visually for yourself can be a thrill.

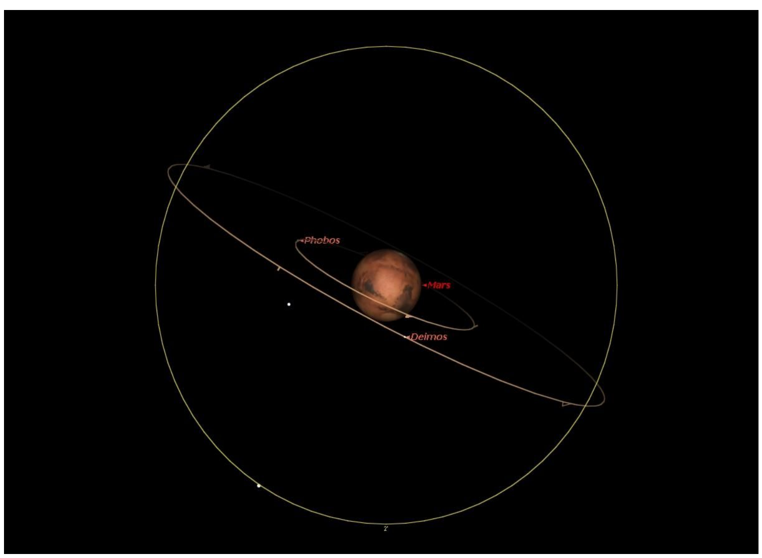
One of the key challenges in spotting many of the fainter moons is the fact that they lie so

close inside the glare of their respective host planet. For example, +11th magnitude Phobos wouldn't be all that tough on its own, were it not for the fact that it always lies close to dazzling Mars. 10 magnitudes equals a 10,000-fold change in brightness, and the fact that most of these moons are swamped out in glare is what makes them so tough to see. This is also why many of them weren't discovered until later on.

But don't despair. One thing you can use that's relatively easy to construct is an occulting bar eyepiece. This will allow you to hide the dazzle of the planet behind the bar while scanning the suspect area to the side of the primary planet for the faint moon. Steady skies and well collimated optics are a must as well, and don't be afraid to crank up the magnification in your quest. We mentioned such a technique previously as a method to tease out the white dwarf star Sirius B (See *Can You Spy Sirius B?*) in the years to come.

What follows is a comprehensive list of the well known 'easy ones,' along with some challenges.
We included a handy drill down of magnitudes, orbital periods and maximum separations for the moons of each planet right around opposition. For the more difficult moons, we also noted the circumstances of their discovery, just to give the reader some idea what it takes to see these fleeting worlds. Remember, though, many of those old scopes used speculum metal mirrors which were vastly inferior to commercial optics available today. You may have a large Dobsonian scope available that rivals or even out performs these 'scopes of yore!

Mars- The two tiny moons of Mars are a challenge, as it's only possible to nab them visually near opposition, which occurs about once every 26 months. Mars next reaches opposition on July 27th, 2018.



Mars versus its two moons near opposition with a 2' field of view. Image credit: Starry Night.

Phobos:

Magnitude: +11.3
Orbital period: 7 hours 39 minutes
Maximum separation: 16”

Deimos:

Magnitude: +12.3
Orbital period: 1 day, 6 hours and 20 minutes
Maximum separation: 54”

The moons of Mars were discovered by American astronomer Asaph Hall during the favorable 1877 opposition of Mars using the 26-inch refracting telescope based at the U.S. Naval Observatory in Foggy Bottom, Washington D.C.

Jupiter and Io. Image credit: Dave Dickinson.

Jupiter- Though the largest planet in our solar system also has the largest number of moons at 67, only the four bright Galilean moons are easily observable, although owners of large light buckets might just be able to tease out another two. Jupiter reaches opposition this year on April 7th, 2017.

Ganymede:

Magnitude: +4.6
Orbital period: 7.2 days
Maximum separation: 5’

Callisto:

Magnitude: +5.7
Orbital period: 16.7 days
Maximum separation: 9’

Io:

Magnitude: +5.0
Orbital period: 1.8 days
Maximum separation: 1’ 50”

Europa:

Magnitude: +5.3
Orbital period: 3.6 days
Maximum separation: 3’

Amalthea:

Magnitude: +14.3
Orbital period: 11 hours 57 minutes
Maximum separation: 33”

Himalia:

Magnitude: +15
Orbital period: 250.2 days
Maximum separation: 52’

Note that Amalthea was the first of Jupiter’s moons discovered after the four Galilean moons. Amalthea was first spotted in 1892 by E. E. Barnard using the 36” refractor at the Lick Observatory. Himalia was also discovered at Lick by Charles Dillon Perrine in 1904.

Saturn- With a total number of moons at 62, six moons of Saturn are easily observable with a backyard telescope, though keen-eyed observers might just be able to tease out another two. In 2017, Saturn reaches opposition on June 15th.

Titan:

Magnitude: +8.5
Orbital period: 16 days
Maximum separation: 3’

Rhea:

Magnitude: +10.0
Orbital period: 4.5 days
Maximum separation: 1' 12"

Iapetus:

Magnitude: (variable) +10.2 to +11.9
Orbital period: 79 days
Maximum separation: 9'

Dione:

Magnitude: +10.4
Orbital period: 2.7 days
Maximum separation: 46"

Tethys:

Magnitude: +10.2
Orbital period: 1.9 days
Maximum separation: 35"

Mimas:

Magnitude: +12.9
Orbital period: 0.9 days
Maximum separation: 18"

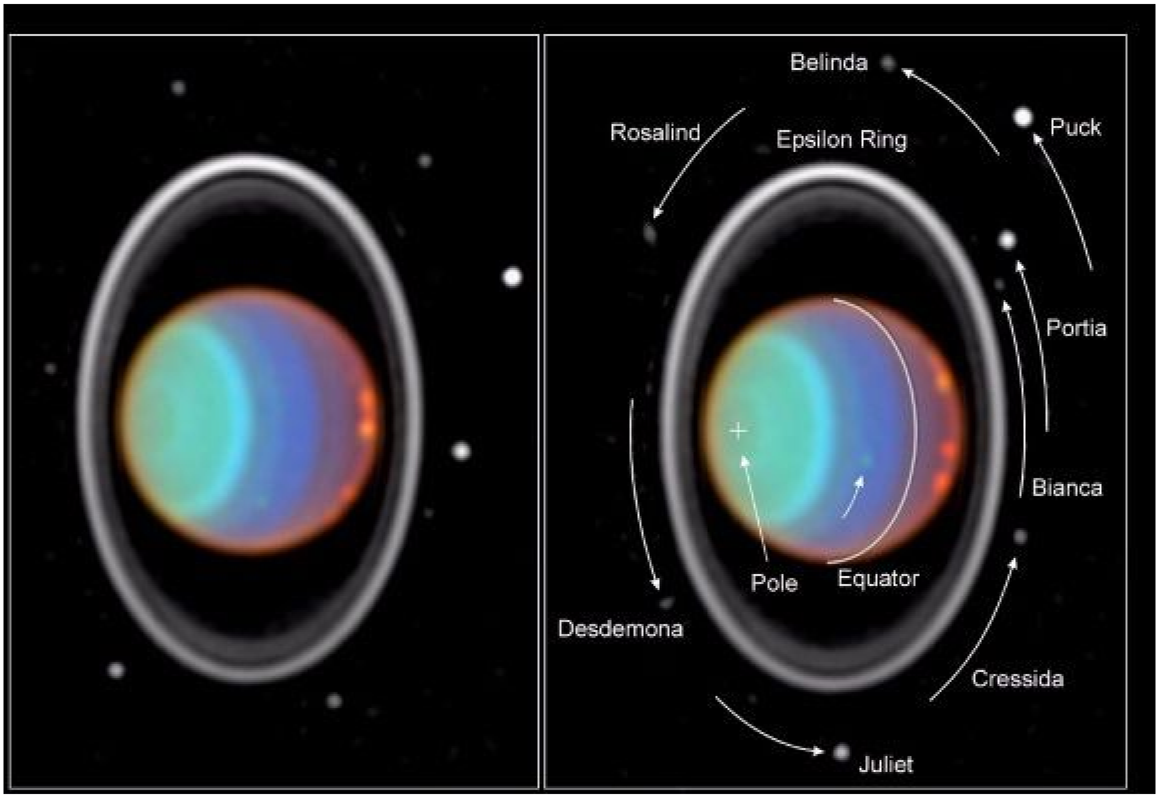
Hyperion:

Magnitude: +14.1
Orbital period: 21.3 days
Maximum separation: 3' 30"

Phoebe:

Magnitude: +16.6
Orbital period: 541 days
Maximum separation: 27'

Hyperion was discovered by William Bond using the Harvard observatory's 15" refractor in 1848, and Phoebe was the first moon discovered photographically by William Pickering in 1899.



Uranus with its rings and moons. Credit: NASA/Hubble

<u>Uranus-</u> All of the moons of the ice giant planets are tough. Though Uranus has a total of 27 moons, only five of them might be spied using a backyard scope. Uranus next reaches opposition on October 19th, 2017.

Titania

Magnitude: +13.9
Orbital period:
Maximum separation: 28"

Oberon

Magnitude: +14.1
Orbital period: 8.7 days
Maximum separation: 40"

Umbriel

Magnitude: +15
Orbital period: 4.1 days
Maximum separation: 15”

Ariel

Magnitude: +14.3
Orbital period: 2.5 days
Maximum separation: 13”

Miranda

Magnitude: +16.5
Orbital period: 1.4 days
Maximum separation: 9”

The first two moons of Uranus, Titania and Oberon, were discovered by William Herschel in 1787 using his 49.5” telescope, the largest of its day.

Neptune- With a total number of moons numbering 14, two are within reach of the skilled amateur observer. Opposition for Neptune is coming right up on September 5th, 2017.

Triton

Magnitude: +13.5
Orbital period: 5.9 days
Maximum separation: 15”

Nereid

Magnitude: +18.7
Orbital period: 0.3 days
Maximum separation: 6’40”

Triton was discovered by William Lassell using a 24” reflector in 1846, just 17 days after the discovery of Neptune itself. Nereid wasn’t found until 1949 by Gerard Kuiper.

Pluto-Yes: it is possible to spy Charon from Earth… as amateur astronomers have proven in recent years. A good time to try in 2017 is during this year's July 10th opposition.

Charon

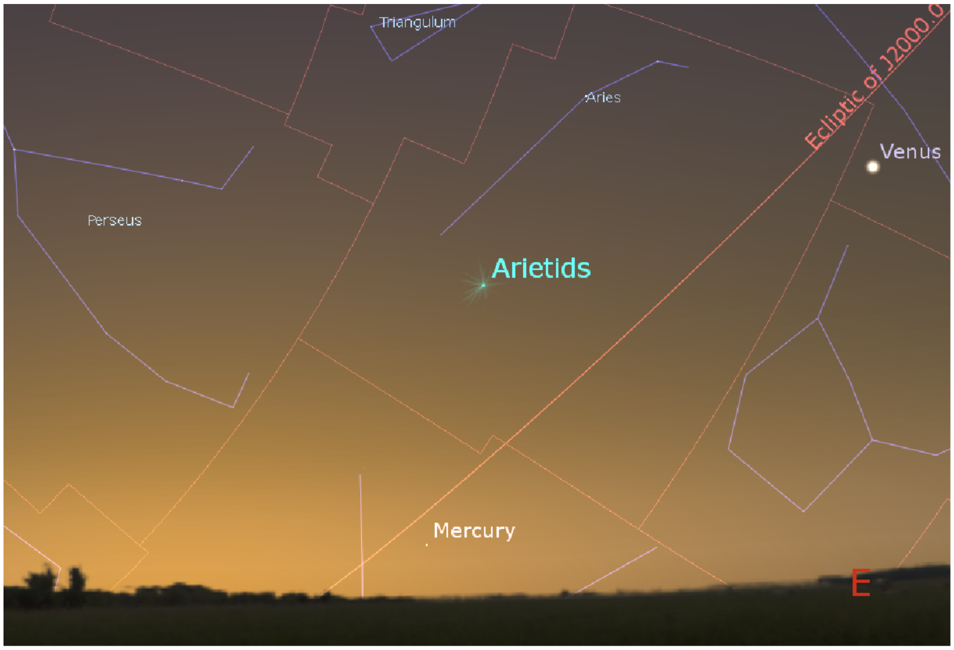
Magnitude: +16
Orbital period: 6.4 days
Maximum separation: 0.8”

In order to cross off some of the more difficult targets on the list, you'll need to know exactly when these moons are at their greatest elongation. *Sky and Telescope* has some great apps in the case of Jupiter and Saturn… the PDS Rings node can also generate corkscrew charts of lesser known moons, and Starry Night has 'em as well. In addition, we tend to publish cork screw charts for moons right around respective oppositions for *Universe Today.*

Good luck in crossing off some of these faint moons from your astronomical life list!

June 2017

Wednesday, June 7th: The Daytime Arietids Meteor Shower

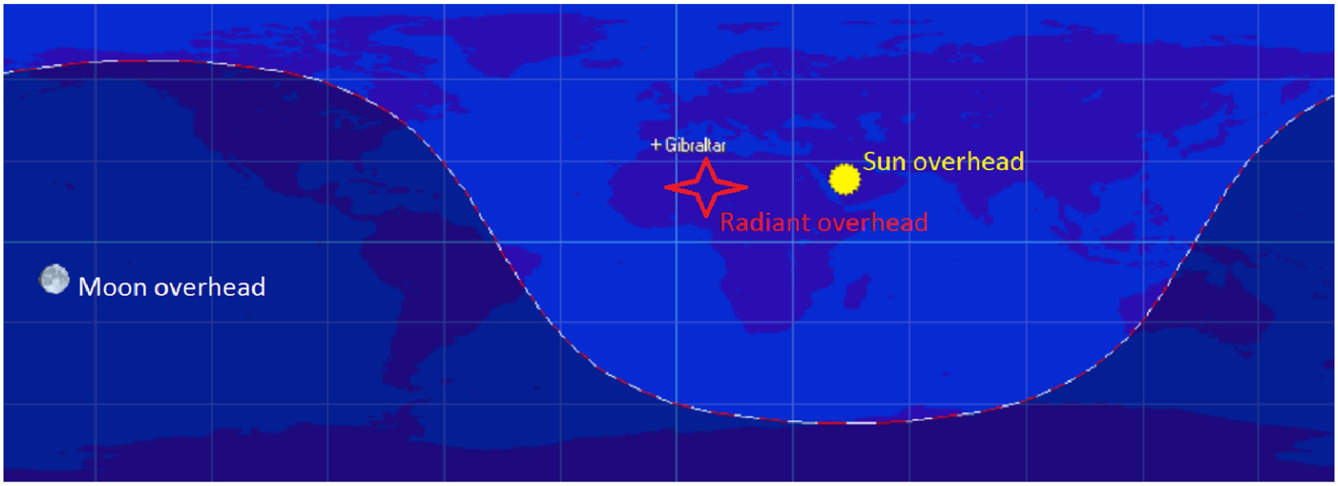


The Arietid radiant. Looking east from North Africa at sunrise on June 7th. Credit: Stellarium.

The Arietid meteors are expected to peak on June 7th at 10:00 Universal Time (UT), favoring Europe and Northern Africa. The shower is active for a five week from May 22nd to July 2nd and can vary with a Zenithal Hourly Rate (ZHR) of up to 60 meteors per hour. In 2017, the Arietids are expected to produce a maximum ideal ZHR of 30 meteors per hour. The exact radiant of the Arietids isn't precisely known due to the daytime nature of this shower, but seems to be located in Aries near the star 41 Arietis. A daytime shower, you may just see an early harbinger of this elusive shower gracing the early dawn.

The Moon is at 95% illuminated, waxing gibbous at the peak of the Arietids, making **2017 an unfavorable year** for this shower, though of course, the radiant is located only 28 degrees from the Sun at the shower's peak. In previous years, the Arietids produced anywhere from a ZHR of 30 to 60.

The Arietid meteors strike the Earth at a moderate/fast velocity of 38 km/s, and produce an average number of fireballs with an *r* = 2.8. The source of the Arietids is asteroid 1566 Icarus.



The radiant vs the Sun and Moon on June 7th at 10:00 UT. Created using Orbitron.

The daytime Arietids were first detected by the Jodrell Bank radio telescope in 1947.

Thursday/Friday, June 8th/9th: A Full 'MiniMoon'

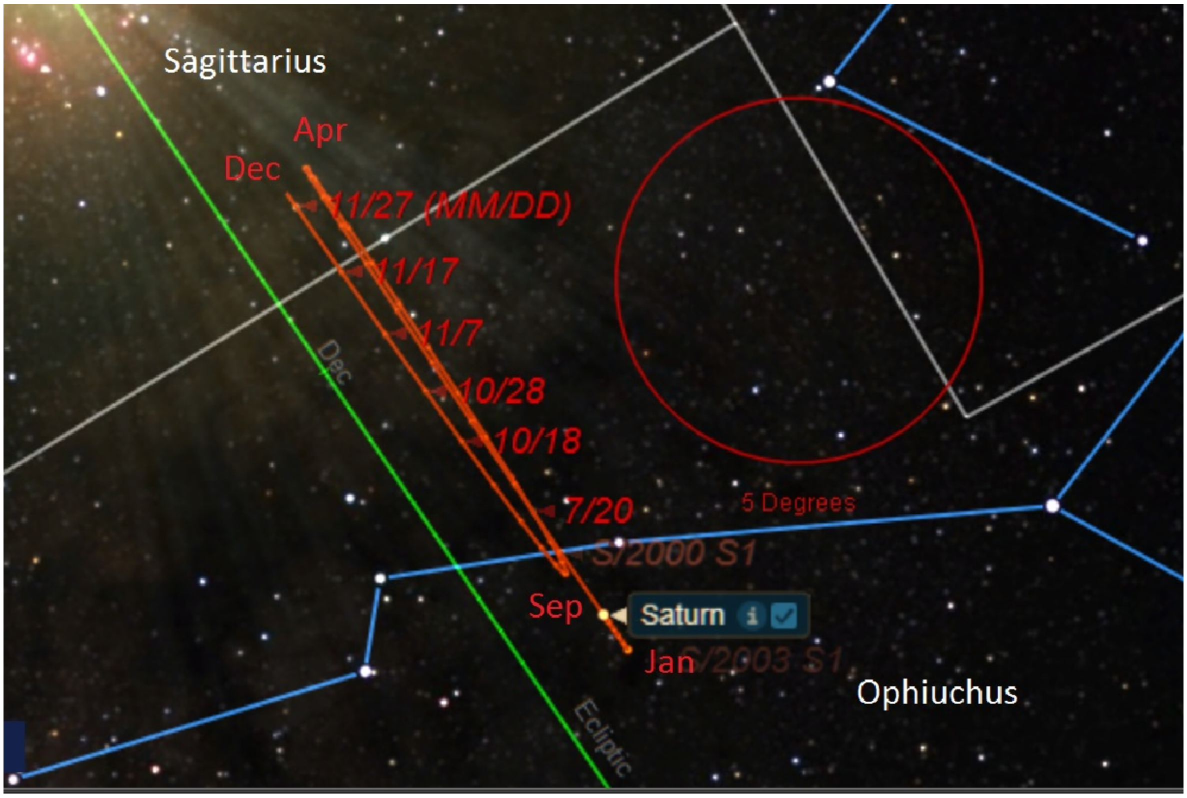
Full Moon. Image credit: NASA

A Full 'MiniMoon' occurs. Like Blue and Black Moons, this is more of a cultural phenomenon than a true astronomical event. The Moon's orbit is elliptical, taking it from 362,600 to 405,400 kilometer from the Earth in the course of its 27.55 day anomalistic orbit from one apogee to the next. For the purposes of this guide, we consider a 'SuperMoon' as when the Full Moon occurs within 24 hours of perigee, and a 'MiniMoon as when the Full Moon occurs within 24 hours of apogee. From the Earth, the Moon varies in apparent size from 29.3” to 34.1” across. In 2017, the Moon reaches apogee on June 8th at 22:22 Universal Time (UT) at 406,401 kilometers distant, 14 hours before Full on June 9th.

This is the most distant Mini-Moon until 2029.

The July 27th, 2018 MiniMoon also features a total lunar eclipse.

Thursday, June 15th: Saturn Reaches Opposition



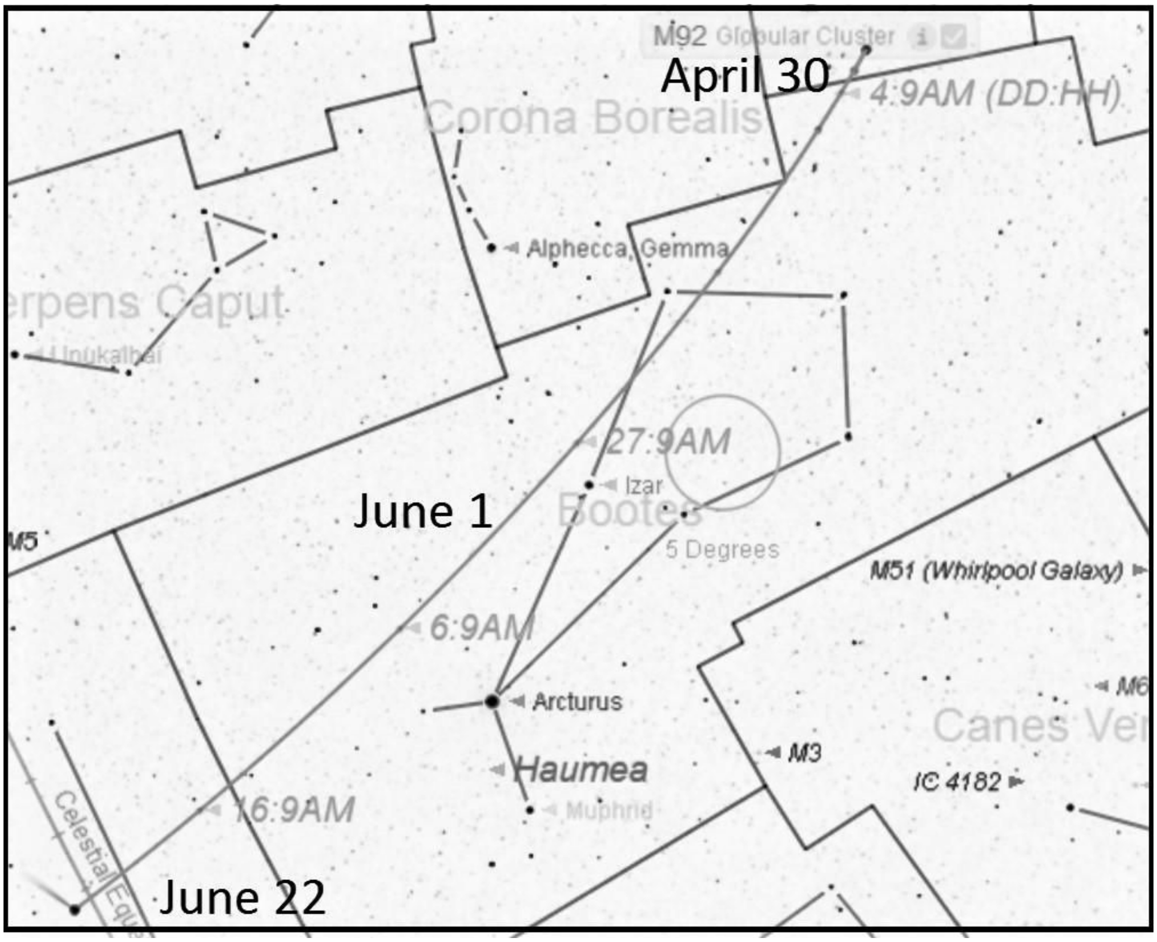
The path of Saturn through 2017. Credit: Starry Night Education software.

The planet Saturn reaches opposition for 2017 on June 15th at 10:00 Universal Time (UT). Opposition for 2017 occurs in the constellation Ophiuchus. In 2017, Saturn wanders along the ecliptic from Ophiuchus to Sagittarius. Oppositions for Saturn occur every 378 days, and mark the entrance of the planet into the evening sky about a month prior and the prime season for imaging and observing the planet. The last opposition for Saturn occurred on June 3rd, 2016 and the next is June 27th, 2018. During opposition 2017, Saturn shines at magnitude +0.01 and displays a disk 18” (43” with rings) across. Saturn is 1.35 billion kilometers or 9.0 astronomical units (AU) from the Earth during this year's opposition. With a declination of -22 degrees, this year's opposition favors the southern hemisphere. Saturn's rings are tilted at their widest (27 degrees) in 2017, and will now head towards edge-on once again in 2025.

Saturn by Paul Stewart. https://upsidedownastronomer.wordpress.com/

Opposition is also a great time to observe Saturn's moons. At the telescope eyepiece, Titan is readily apparent, shining at magnitude +8. Rhea, Dione, Tethys, Enceladus and Iapetus are also visible through a small telescopes, ranging in brightness from magnitudes +9 to +12.

Thursday, June 15th: Comet C/2015 V2 Johnson at its Brightest



The path of Comet C/2015 V2 Johnson from April 30th to June 22nd. Credit: Starry Night.

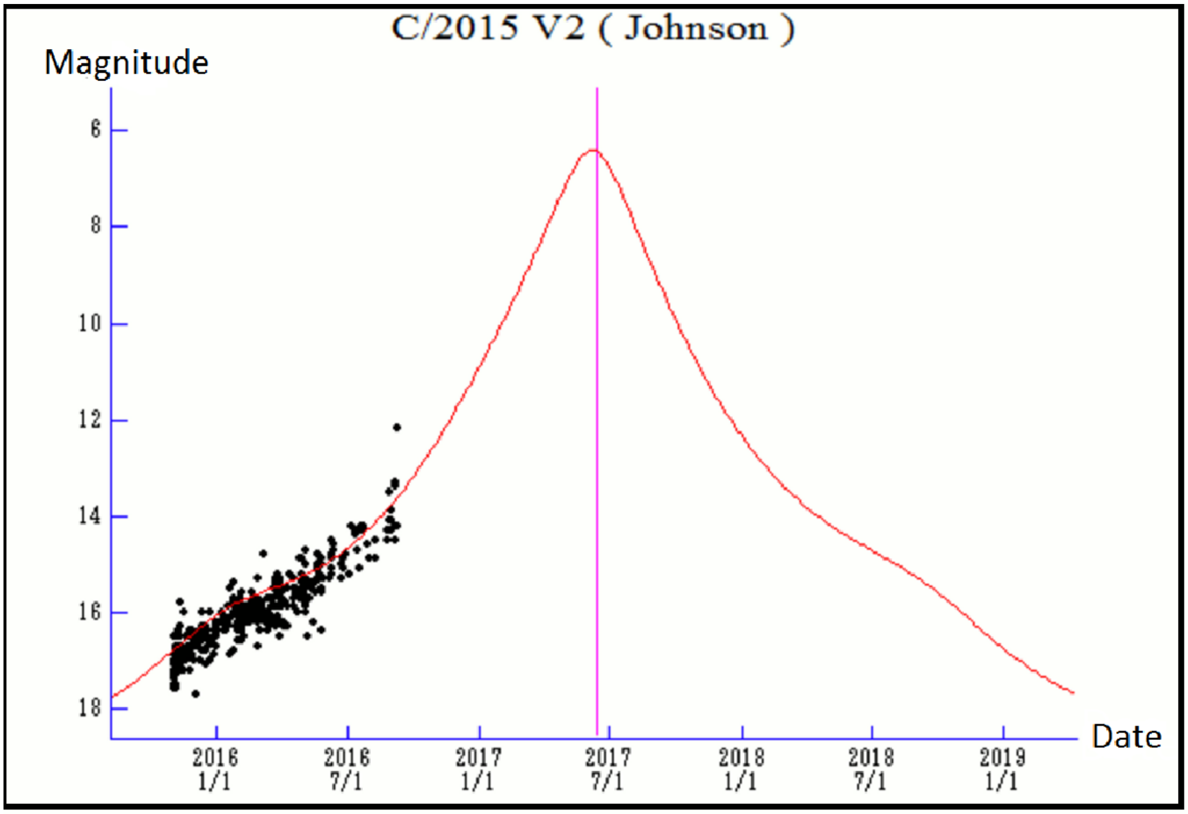
Comet C/2015 V2 Johnson is expected to reach maximum brightness around this date. Discovered by Jess Johnson from the Catalina Sky Survey on November 3rd, 2015, comet C/2015 V2 Johnson orbits the Sun on a hyperbolic orbit set for probable ejection from the solar system. Comet C/2015 V2 Johnson is set to break binocular +10th magnitude brightness in early January 2017, and reach a maximum of +7th magnitude (just below naked eye brightness) in mid-June.

Visibility prospects: At its brightest, Comet C/2015 V2 Johnson will pass through constellations Hercules and Boötes from January through June, and is best visible in the dusk sky 127 degrees from the Sun at maximum brightness. This apparition favors the northern hemisphere until July. The comet reaches perihelion on June 12th, 2017 at 1.64 AU from the Sun, and the comet passes 0.812 AU from the Earth on June 5th. Some notable dates with

destiny for Comet C/2015 V2 Johnson are:

May 4th: Passes near the +3.9 magnitude star Tau Herculis
May 19th : Passes near the +3.4 magnitude star Delta Boötis
May 29th: Passes near the +2.3 magnitude star Izar (Epsilon Boötis)
June 22nd: Crosses the celestial equator southward
This is a well placed summer binocular comet for northern hemisphere observers in 2017.

Expect Comet V2 Johnson to appear as a fuzzy star in binoculars on closest approach.



"When beggars die there are no comets seen; The heavens themselves blaze forth the death of princes."

-William Shakespeare, *Julius Caesar.*

Wednesday, June 21st: The June Solstice

Sunset by Cory Schmitz. https://PhotographingSpace.com

The northward solstice occurs at 4:24 Universal Time (UT), marking the beginning of astronomical summer for the northern hemisphere, and the start of winter for the southern. This is an exact moment when the Sun's declination equals 23.5 degrees north as seen from the Earth. The two lines of latitude where the Sun passes straight through the zenith during either solstice are known as the Tropic of Cancer (northward) and the Tropic of Capricorn (southward), although in modern times, the solstices occur in the astronomical constellations Taurus and Sagittarius in modern times, thanks to precession.

In the 21st century, the June Solstice last falls on June 21st or June 20th and will fall on the 20th with more frequency in the last half of the century.

The solstice (meaning 'stationary Sun' in Latin) means that the northern rotational pole of the Earth is now tipped towards the Sun, which will now begin its long apparent journey southward again until December. In 2017, earliest sunrise actually occurs on June 13th (5:31 AM local) and latest sunset occurs on Jun 27th (8:32 PM local) as seen from latitude 40 degrees north.

In the 3rd century BC, Greek mathematician and philosopher Eratosthenes accurately deduced the circumference of the Earth by noting the position of the Sun overhead as seen from a well in Syene, Egypt (located on the Tropic of Cancer) versus the shadow angle on the June solstice from Alexandria.

Thursday, June 22nd: The International Space Station Enters Full Illumination

International Space Station. Credit: NASA

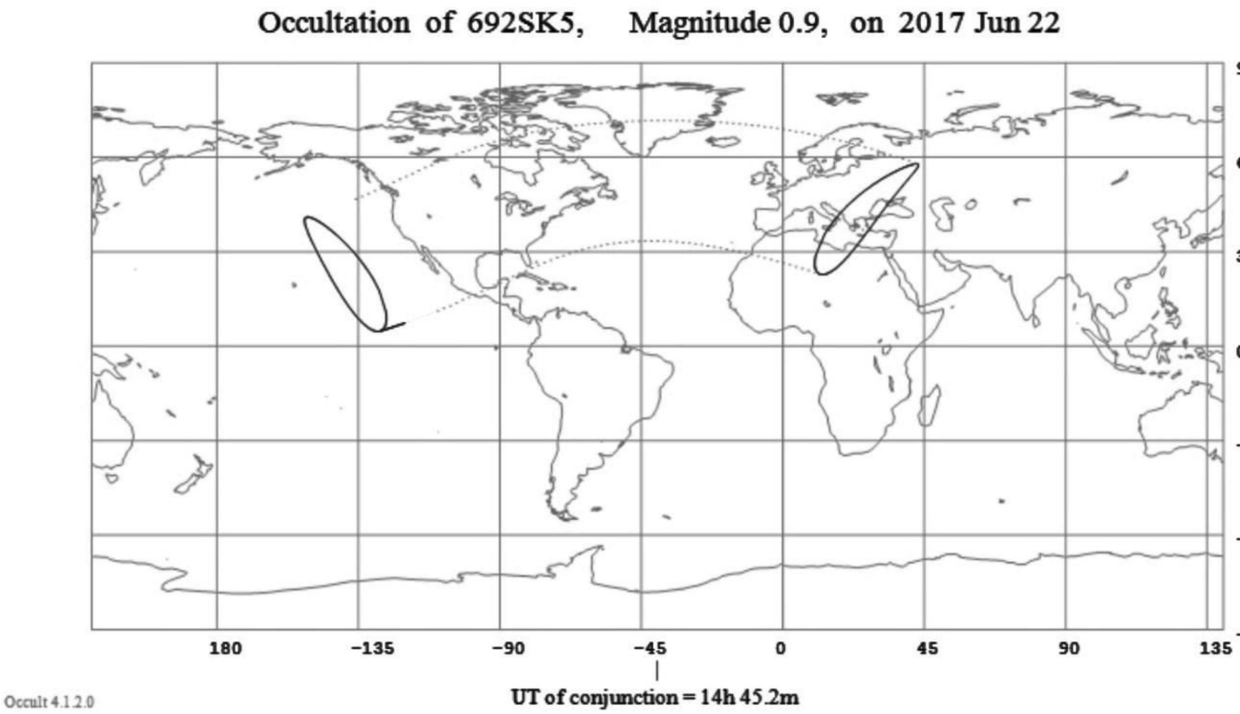
The International Space Station enters a period of full illumination throughout the length of its orbit, favoring the northern hemisphere with multiple visible passes. The period of full illumination begins May 22nd through May 25th, followed by a second season on July 22nd which ends on July 25th. The International Space Station has an orbital inclination of 52 degrees relative to the equator, allowing for access from launching spaceports worldwide. This inclination also assures the the International Space Station reaches periods of full illumination biannually, on the weeks surrounding either solstice. NASA engineers call this 'high beta angle season,' a time when special precautions have to be taken aboard the station to avoid overheating. @OzoneVibe on Twitter once suggested to us that such a season should be known as a FISSION, for 'Four/Five ISS Sightings In One Night.'

Note that these orbital predictions are made while writing this guide late on the year previous... the orbit of the ISS evolves over time, as the station gets periodically boosted using the engines of visiting spacecraft to avoid reentry due to atmospheric drag. These predictions are most likely to be off by a day or so. Follow us on @Astroguyz for updates.

Two seasons of full illumination for the International Space Station can occasionally occur in late May and July, book-ending the solstice.

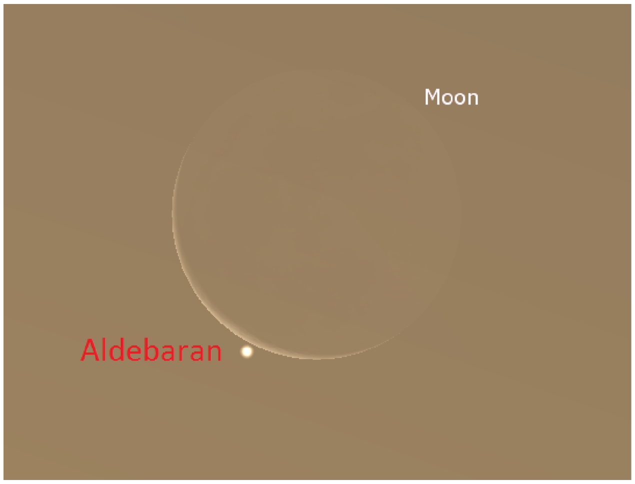
The core Zarya module of the International Space Station was launched from the Baikonur Cosmodrome on November 20th, 1998, and completed 101.081 orbits of the Earth as of July 2016.

Thursday, June 22nd: The Moon occults Aldebaran



The footprint for the June 22nd event. Image credit: Occult 4.2.

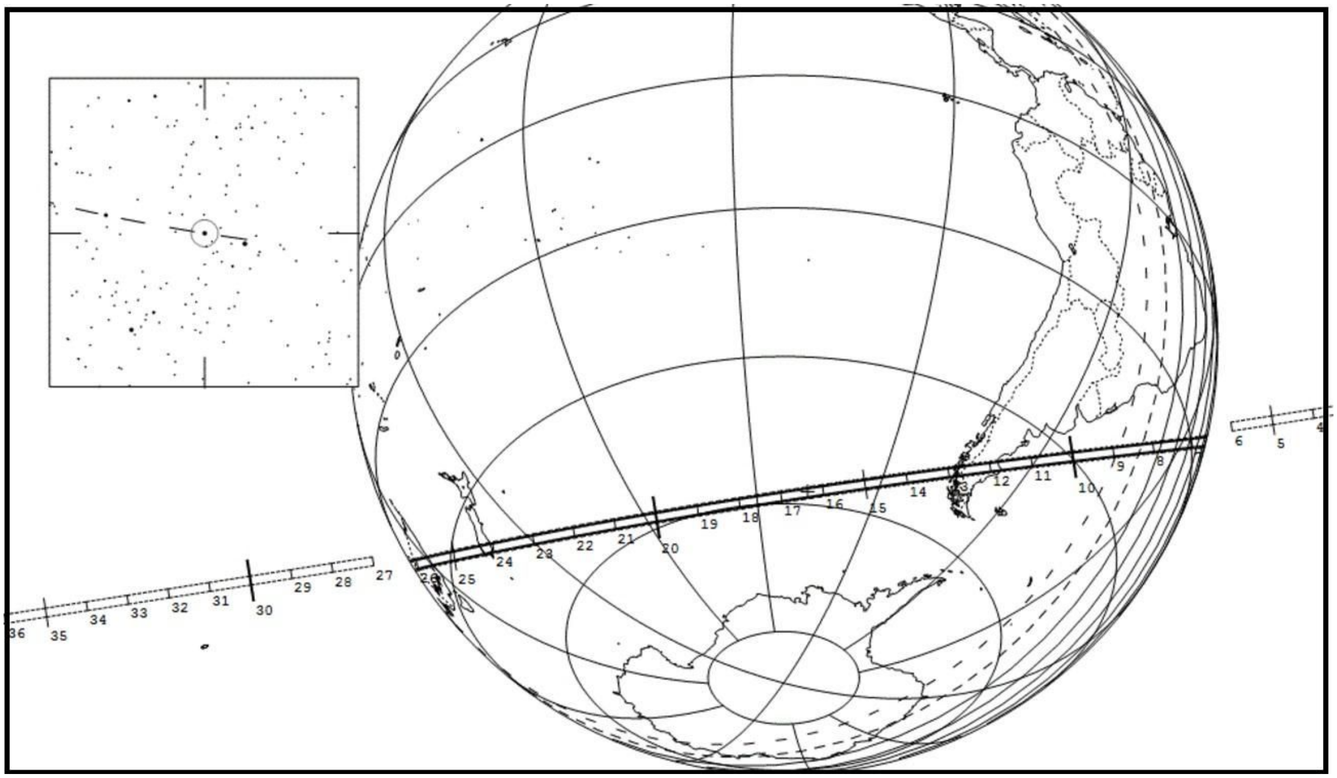
The 4% illuminated waning crescent Moon occults the +0.9 magnitude star Aldebaran. The Moon is two days from New during the event. Both are located 22 degrees west of the Sun at the time of the event. The central time of conjunction is 14:45 Universal Time (UT). The event occurs during the daylight hours over North America and Europe, and under darkness for a small portion of the eastern Pacific, just east of Hawaii. The Moon will next occult Aldebaran on August 16th, 2017. This is occultation 32 in the current series of 49 running from January 29th, 2015 to September 3rd, 2018. This is the first occultation of Aldebaran by the Moon since the star passed solar conjunction on June 1st.



The view on June 22nd at dawn from the eastern Pacific prior to the occultation. Stellarium.

A frequent setting in science fiction, Aldebaran is now also frequently confused with Alderaan, Princess Leia's late homeworld from the *Star Wars* saga.

Friday, June 23rd: Asteroid 602 Marianna occults a Bright Star

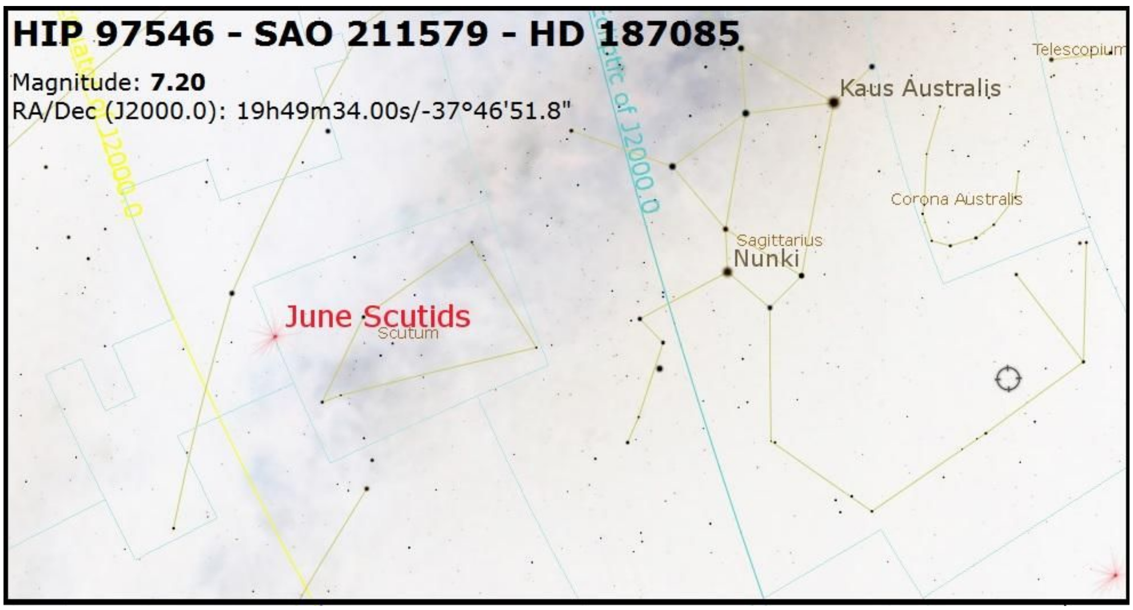


The shadow path of 602 Marianna across Earth from 9:06 to 9:26 UT. Image credit:

Steve Preston's Best Asteroid Occultation Picks for 2017.

Asteroid 602 Marianna occults the +7.3 star HIP 97546. The 139 kilometer wide path crosses the Earth from 9:06 to 9:26 Universal Time (UT). The occultation path crosses Argentina and Chile around 9:12-9:13 UT, and New Zealand and Australia around 9:24 to 9:26 UT. The asteroid's brightness is magnitude +12.7 at the time of the event, and the occultation should last 12.8 seconds of maximum duration as seen from the center line path. The probability rank for this event is 99%. The Moon is a 1% waning crescent during the event. The occulted star is located in the constellation Sagittarius. As seen from southern New Zealand, the occultation occurs under darkness and is located 46 degrees above the horizon. Solar elongation for the occultation is 154 degrees, and the maximum expected magnitude drop is +5.4.

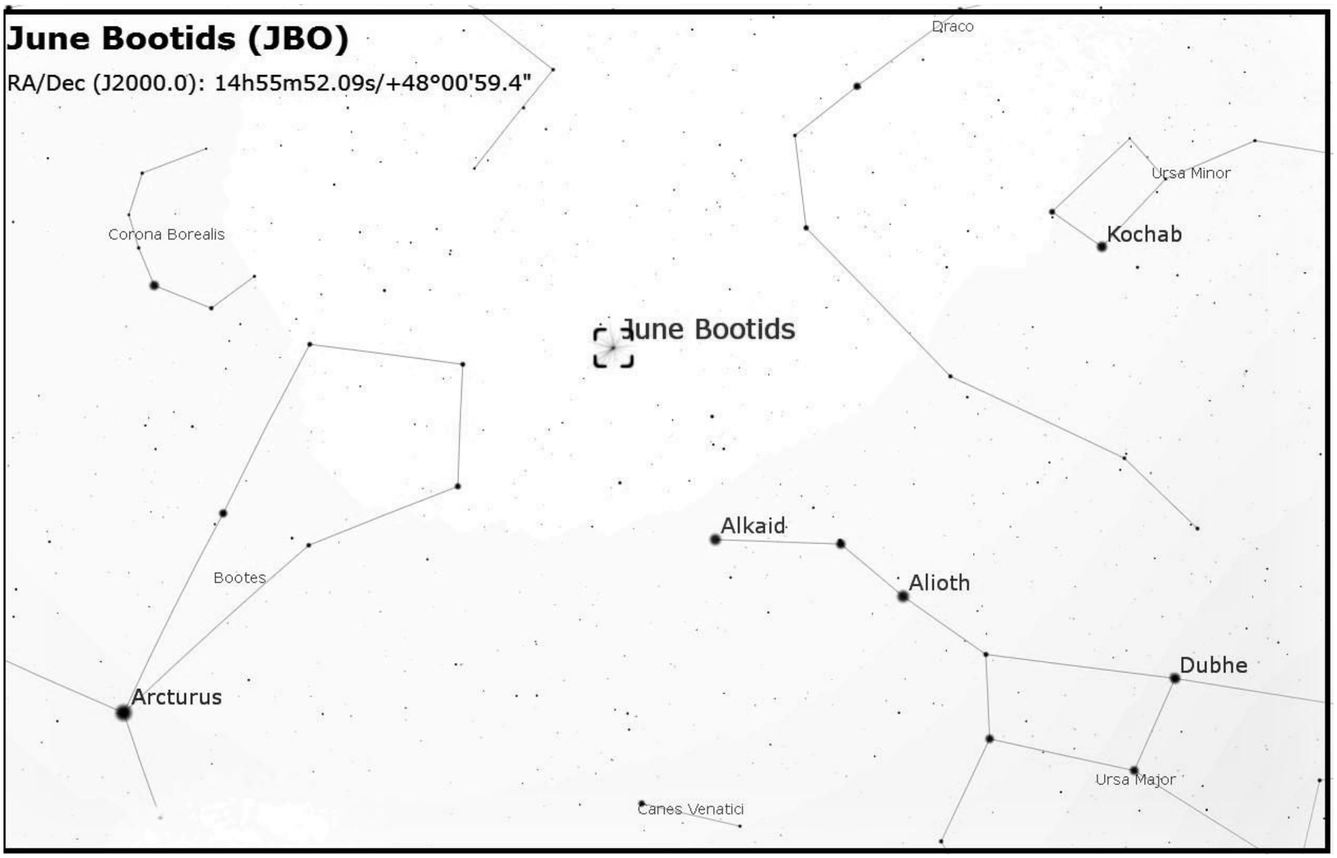
Discovered on February 16th, 1906, asteroid 602 Marianna is one of 41 asteroids discovered by New England Unitarian minister John Hastings Metcalf.



A wide field finder chart for HIP 97546 (lower right). Image credit: Stellarium.

In the pre-photographic era, asteroids were rarely discovered in February. More visual discoveries of asteroids were historically made in the month of September than any other calendar month. In fact, 344 of the first 1,940 numbered asteroids were found in September, more than *twice* the average. The reason: Astronomers of yore typically hunted for asteroids approaching opposition in the anti-sunward direction, which in September lies across the relatively star poor fields of Pisces. In December and June — the months with the lowest numbers of visual discoveries at only 75 and 65 for the first 1,940 numbered asteroids, respectively — the anti-sunward point lies in the star-rich regions of Sagittarius and Gemini.

Tuesday, June 27th: The June Boötid Meteor Shower Peaks

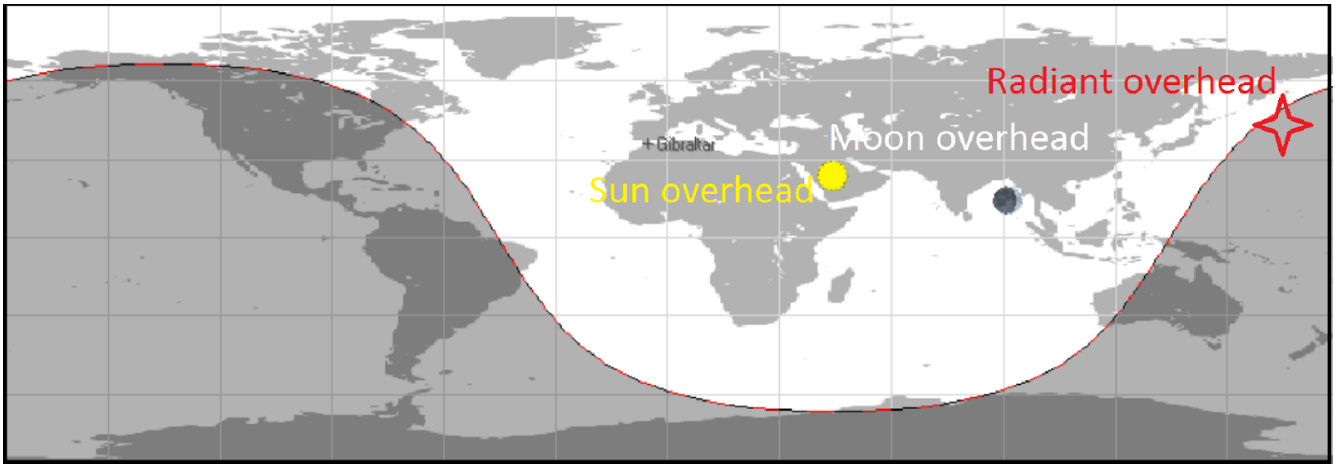


The location of the June Boöotid meteor shower radiant. Credit: Stellarium.

The June Boötid meteors are expected to peak on June 27th at 09:00 UT, favoring western North America. The shower is active for a two week span from June 22nd to July 2nd, and can vary with a Zenithal Hourly Rate (ZHR) of 50-100 meteors per hour. In 2017, the June Boötids are expected follow this trend, and produce a variable maximum ideal ZHR up to 100 meteors per hour. The radiant of the June Boötids is located at right ascension 14 Hours 55 minutes, declination 48 degrees north at the time of the peak, in the constellation of Boötes.

The Moon is a 15% illuminated waxing crescent at the peak of the June Boötids, making **2017 a favorable year** for this shower. In previous years, the June Boötids produced a ZHR topping 100 per hour in 1998 and 2004.

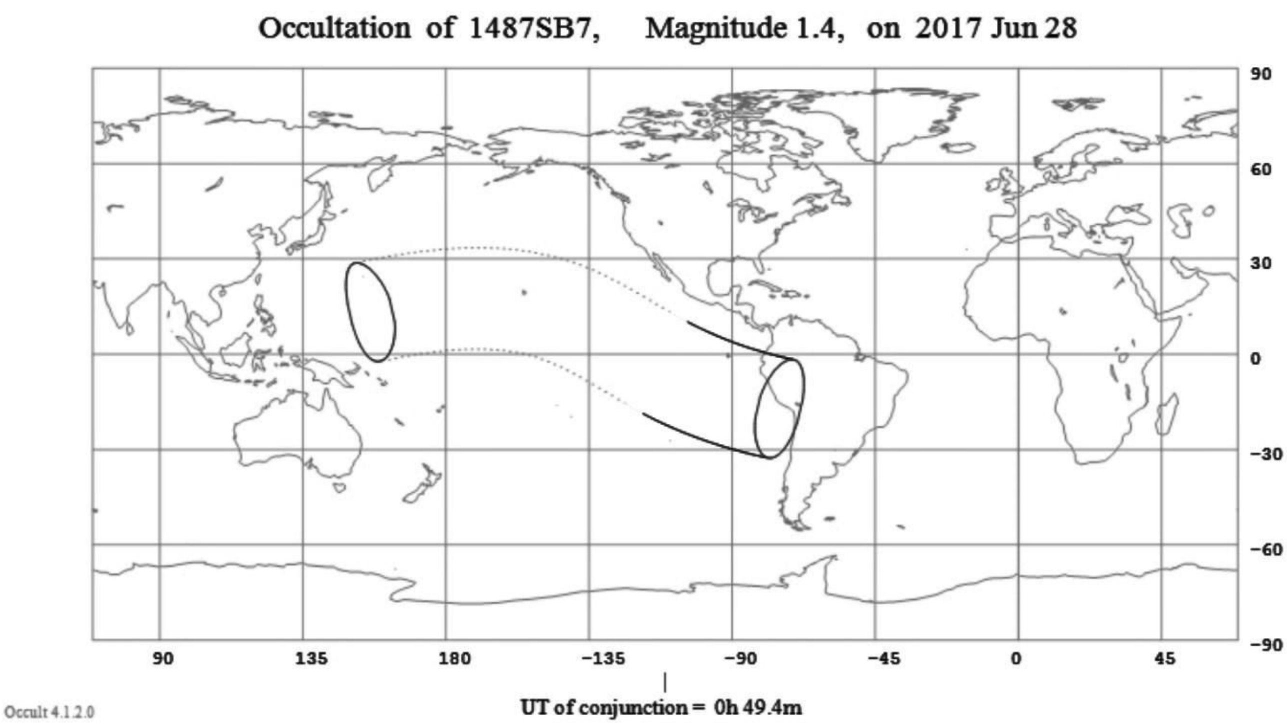
The June Boötid meteors strike the Earth at a moderate/fast velocity of 18 km/s, and produce many fireballs with an *r* value of 2.2. The source of the June Boötids is comet 7P/Pons-Winnecke. The source comet for the June Boötids orbits the Sun once every 6.4 years, and most recently reached perihelion on January 30th, 2015.



The orientation of the radiant vs the Sun, Moon and Earth's shadow on June 27th at 9:00 UT. (Created using Orbitron)

A periodic comet discovered 1819, Comet 7P/Pons-Winnecke passed just 0.04 AU (6 million kilometers) from the Earth in June 1927. The comet won't make a close passage by Earth during this century.

Wednesday, June 28th: The Moon occults Regulus



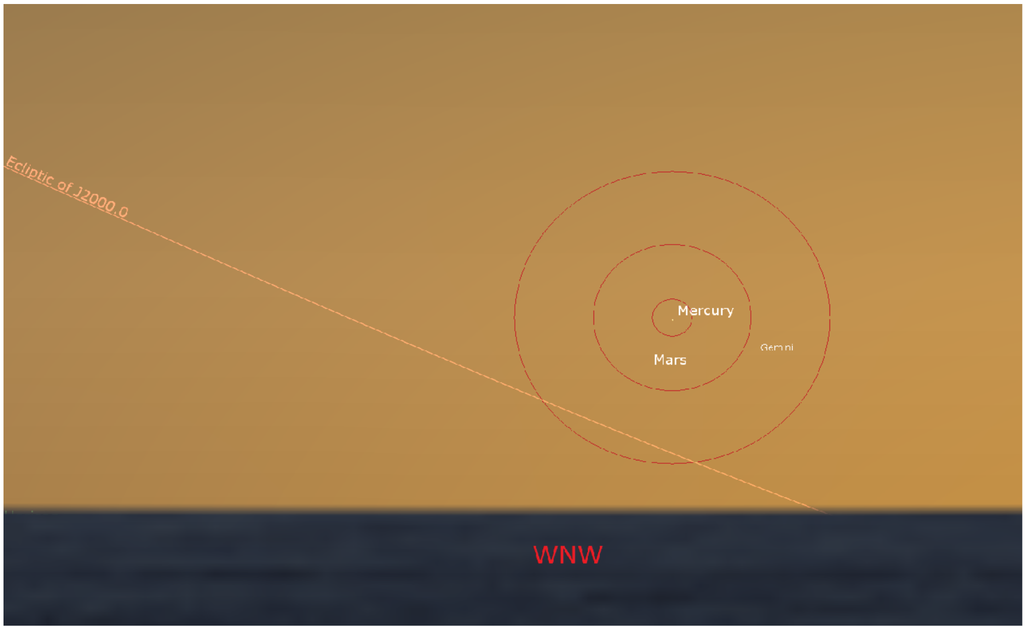
The footprint of the June 28th occultation of Regulus by the Moon. Image credit Occult 4.2.

The 20% illuminated waxing crescent Moon occults the +1.4 magnitude star Regulus. The Moon is 4 days past New during the event. Both are located 53 degrees east of the Sun at the time of the event. The central time of conjunction is 00:49 Universal Time (UT). The event occurs during the daylight hours over Hawaii, and under darkness for northwestern South America, including Peru, Ecuador and the Galapagos Islands. The Moon will next occult Regulus on July 25th. This is the 8th occultation in the current series of 19 running from December 18th, 2016 to April 24th, 2018. Mexico and the southern United States will see the pair pass just 15-20' apart on the evening of the evening of June 28th.

The view on June 28th from the Galapagos Islands. Image credit: Stellarium.

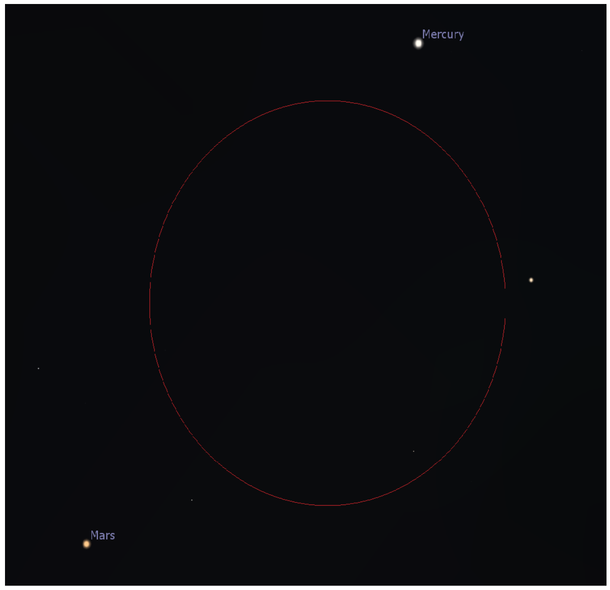
A close conjunction of Jupiter and Regulus in 3 B.C. is one of the proposed suspects presented over the years for the Star of Bethlehem.

Wednesday, June 28th: A Close Conjunction of Mercury and Mars



Looking WNW just after sunset from latitude 30 degrees north. Credit: Stellarium.

Mercury and Mars pass within 0.8 degrees (48' arc minutes) of each other in a close conjunction on June 28th. Closest conjunction occurs at 20:00 Universal Time (UT). Mercury shines at magnitude -0.5 and is 5.2” arc seconds in diameter (94% illuminated), and Mars shines at magnitude +1.7 and is 3.6” arc seconds in diameter at the time of closest approach. The conjunction occurs in the astronomical constellation Gemini, 9 degrees east of the Sun in the dusk sky. Mercury is 194 million kilometers or 1.3 Astronomical Units (AU),and Mars is 391 million kilometers or 2.6 AU distant during the conjunction. This equates to 11 light minutes for Mercury and 22 light minutes for Mars. This will be the last chance to spy Mars before it reaches solar conjunction late next month on July 27th.



Mercury with Mars on closest approach with a one degree field of view. Credit: Stellarium.

On August 11th, 2079, Mercury will occult Mars as seen from the Earth for the only time this century.

June's Challenge: Lights in the Sky

Is that mystery streak a meteor train, a reentry or E.T.?

A painting of the great meteor procession of 1860. Fredric Church, image in the public domain.

It happens a few times every year.

We wake up, pour our morning coffee, power up our laptop and phone, and prepare to engage the day.

It's not long before the messages start pouring in. 'Bright fireball over the U.S. West Coast!' 'Major event lights up the California skies!' and variations thereof. Memories of Chelyabinsk come immediately to mind. A bit of digging reveals some videos and a few authentic-looking stills.

Now, I always like to look these over myself before reading just what other experts might think. Chelyabinsk first grabbed our attention when we saw the first videos recording the shock wave of sound generated by the blast. “That sucker was close,” we suddenly realized.

One event in early 2015 was less spectacular, but still interesting: the nighttime reentry of the Long March CZ-7 rocket body as it broke up over the U.S. West Coast.

How do we know this, and what do we look for? Is that flash a meteor, bolide, a satellite reentry, or something stranger still?

Most good meteor footage almost always comes from video systems that are already up and running when the event occurs, to include security and car dash cameras and mobile phones already recording an event. How fast can YOU have your smartphone camera out and running? If the event occurs on a Friday or Saturday night with lots of folks out on the town on a clear evening, we might see multiple captures come streaming in of the event. Just such a fireball was witnessed over the United Kingdom on Friday evening a few years back.

Likewise, the fakes are never far behind. We've seen 'em all, though you're welcome to try and stump us. Such 'meteor-wrongs' that are commonly circulated are the reentry of Mir, the 1992 Peekskill meteor, Chelyabinsk, the reentry of Hayabusa, and screen grabs from the flick *Armageddon*... has anyone ever been fooled by this one?

Meteors generally have a very swift motion, and occur with a greater frequency as the observer rotates forward into the path of its motion around the Sun past local midnight. Remember, its the front of the windshield that picks up the bug splatter, rolling down the highway.

Evening meteors, however, can have a dramatic slow stately motion across the sky, as they struggle to catch up with the Earth. If they reach a brilliance of magnitude -14 – about one whole brighter than magnitude brighter than a Full Moon – said meteor is known as a *bolide*.

Sometimes such a fireball can begun shedding fiery debris, in a dramatic display known as a *meteor train* or *meteor precession*. Such an event was witnessed over the northeastern United States on July 20th, 1860.

Bright meteors may exhibit colors, hinting at chemical competition. Green, for nickel is typically seen. *Meteorite Men's* Geoffrey Notkin once told us a good rule of thumb: if you hear an accompanying sonic boom a few minutes after seeing a meteor, it's close. Folks often think what they saw went down behind a hill or tree, when it was actually likely more than 50 miles distant — if it hit the ground at all.

Corkscrews and electrophonic sound

Meteors can also occasionally exhibit bizarre and seemingly impossible behavior. For example, corkscrewing meteors have long been reported. This motion should be impossible, though seasoned observers still mention this phenomenon. Likewise, observers occasionally report a hissing or crackling noise accompanying a bright bolide, though such an event occurs high in the mostly airless upper atmosphere... what's going on here? Well, there's good

evidence to suggest that, like aurora, meteors can set up a temporary localized electric field, using nearby wires, structures or grass and trees.

Is that a meteor or a reentry? Reentries move slower still, and will shed lots of debris. Here's what we're looking at to judge suspect sighting as a reentry:

Heavens-Above: A great clearing house for satellite passes by location. One great tool is that Heavens-Above will generate a pass map for your location juxtaposed over a sky chart.

Aerospace Corp current reentries: Follows upcoming reentries of larger debris with refined orbits.

Space-Track: The U.S. Joint Space Operations Command's tracking center for artificial objects in orbit around Earth. Access is available to backyard satellite spotters with free registration. The most accurate source for swiftly evolving orbital elements.

SeeSat-L: This message board always lights up with chatter whenever a possible reentry is seen worldwide.

Stranger Skies

Bizarre sights also await the keen-eyed. A tumbling rocket booster can often flare in a manner similar to Iridium satellites. Satellites way out in geostationary orbit can flare briefly into naked eye visibility during 'GEOSat flare season' on the weeks surrounding either equinox.

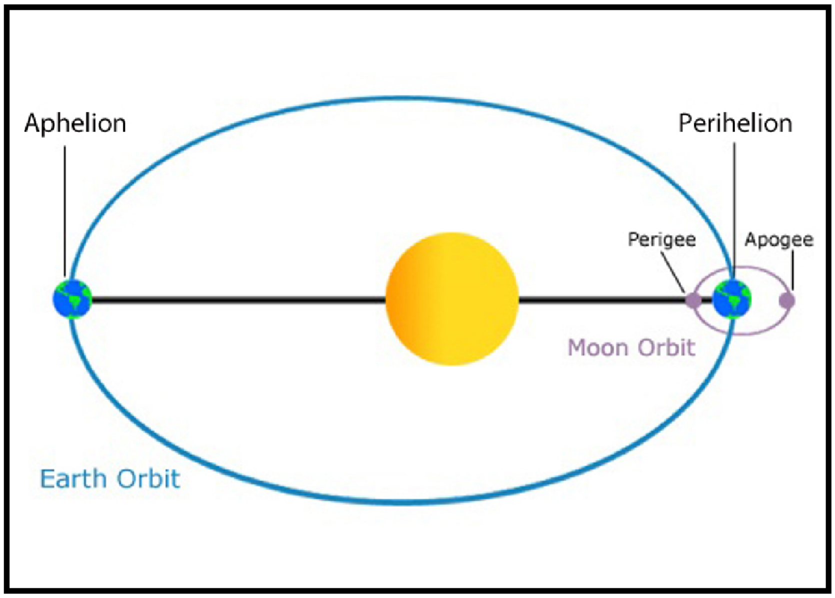
Some gamma-ray bursts such as GRB 080319B flare up briefly above magnitude +6 into naked eye visibility from far across the Universe. As of yet, there's never been a reliable observer sighting of such an event, though it should be possible. Probably someone far back in humanity's history witnessed just such a brief flash in the sky, pausing to wonder just what it was...

Going further back still, a nearby supernova or gamma-ray burst would leave a ghostly blue afterglow from Cerenkov radiation as it pummeled our atmosphere. Though pretty, it would also be a deadly planet-sterilizing indigo glow, not something you'd really want to see. Thankfully, we live in the 'Era of Mediocrity,' safely outside of the 25-50 light year 'kill zone' for any potential supernova.

And what if those lights in the sky really where the vanguard of an alien invasion force? Well, if they really did land ray-guns ablaze on the White House lawn, you'll read it first on *Universe Today*!

July 2017

Monday, July 3th: Earth at Aphelion



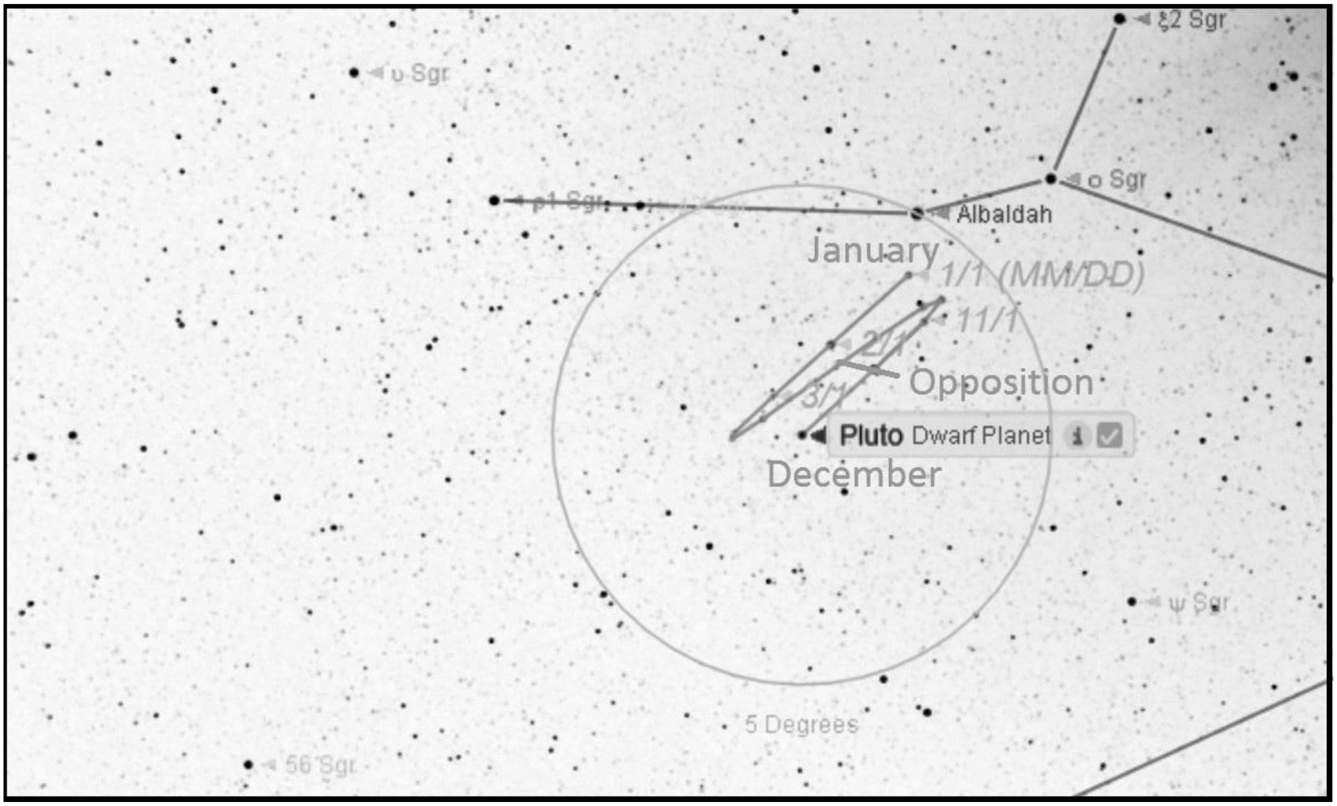
An exaggerated view of the Earth-Moon path around the Sun. Image credit: NASA/NOAA.

Earth reaches aphelion for 2017, or its closest point to the Sun on July 3rd at 20:11 Universal Time (UT) at 1.0167 AU (94.5082 million miles or 152.0962 million kilometers) distant. On this date, the Sun appears 31' 28" in diameter as seen from the Earth. In the current epoch, perihelion actually falls during northern hemisphere winter and aphelion or our farthest point from the Sun occurs during the summer about two weeks after the June solstice.

During the 21st century, aphelion occurs anywhere from July 3rd (next in 2025) to July 7th (next 2067), and the distance for aphelion ranges from 1.0166 AU (94.499 million miles or 152.081 million kilometers) in 2085 to 1.0168 AU (94.5175 million miles or 152.1111 million kilometers) in 2067.

The eccentricity of the Earth's orbit varies from 0.00055 (near circular) to a maximum of 0.067 (6.7%) over a span of roughly 100,000 years as part of what are known as *Milankovitch Cycles*. The current value is of Earth's eccentricity is 0.017 and decreasing.

Monday, July 10th: Pluto reaches Opposition

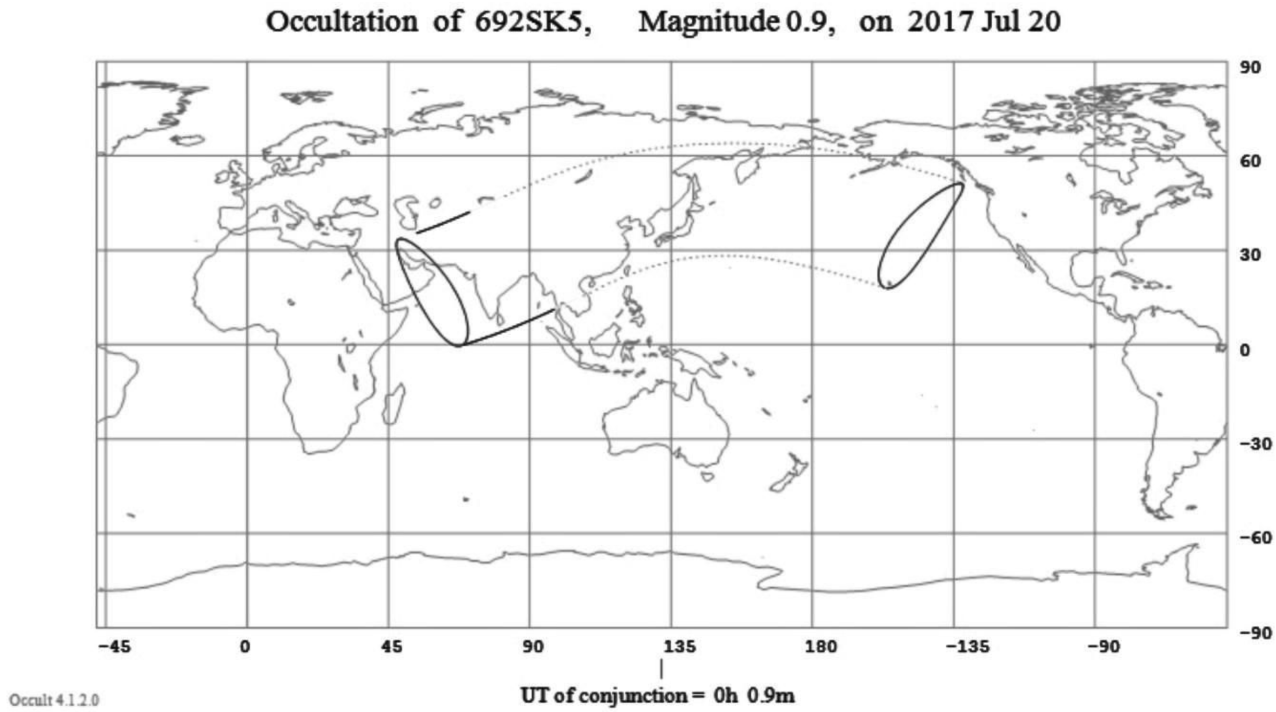


The path of Pluto through 2017. Credit: Starry Night Education Software.

The dwarf planet (née major planet) Pluto reaches opposition for 2017 on July 10th at 4:00 Universal Time (UT). Opposition for 2017 occurs in the constellation Sagittarius. In 2017, Pluto wanders through the constellation Sagittarius near the +3.8 magnitude star Omicron Sagittarii. Pluto does not exit Sagittarius into the astronomical constellation of Capricornus until 2024. Oppositions for Pluto occur about every 367 days, marking the entrance of the planet into the evening sky about a month prior and the prime season for imaging and observing the planet. The last opposition for Pluto occurred on July 7th, 2016 and the next occurs on July 12th, 2018. During opposition 2017, Pluto shines at magnitude +14.2 and displays a disk only 0.1" across. Pluto is 3 billion kilometers or 32.35 astronomical units (AU) from the Earth during this year's opposition. With a declination of -21 degrees, this year's opposition favors the southern hemisphere. Pluto reached perihelion 29.7 AU from the Sun on September 5th, 1989, and is now headed towards aphelion 49.3 AU distant on February 19th, 2114.

Discovered by American astronomer Clyde Tombaugh in 1930, we got our first good look at Pluto and its large moon Charon in July 2015, when NASA's New Horizons spacecraft flew through the system.

Thursday, July 20th: The Moon occults Aldebaran

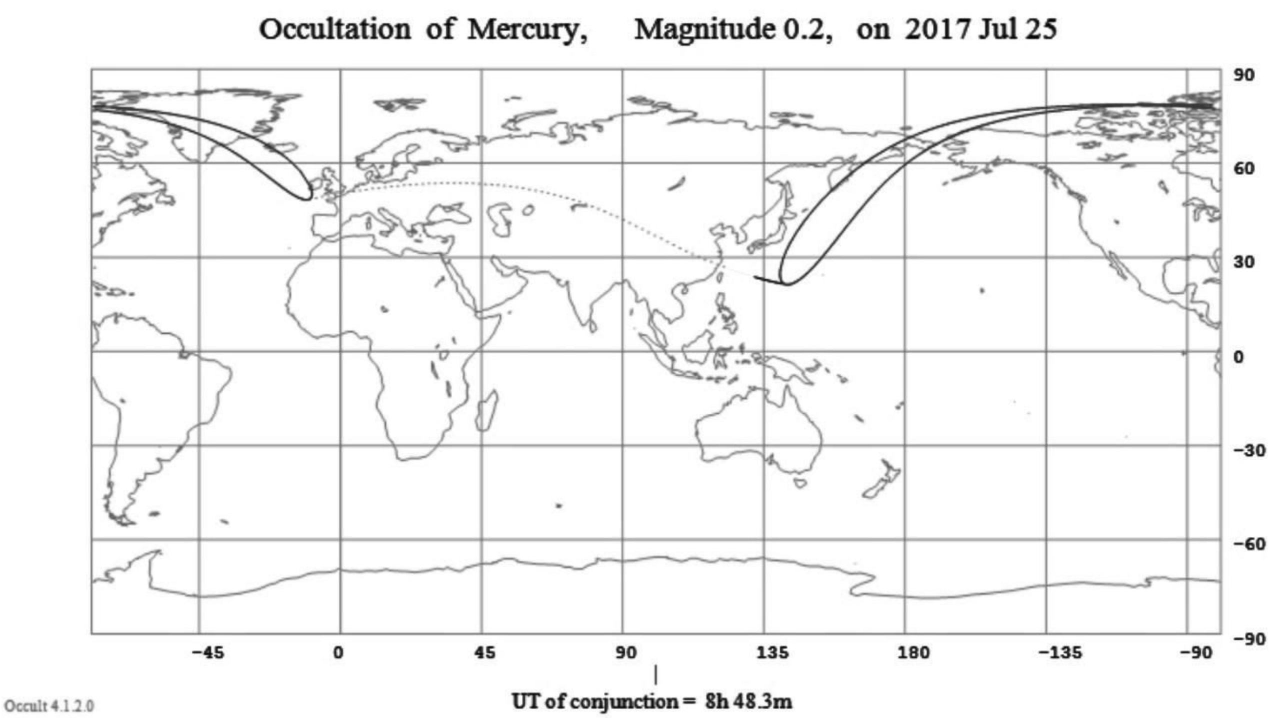


The occultation footprint for the July 20th event. Image credit: Occult 4.2.

The 17% illuminated waning crescent Moon occults +0.9 magnitude Aldebaran. The Moon is 3 days from New during the event. Both are located 48 degrees west of the Sun during the event. The central time of conjunction is 00:01 UT. The event occurs during the daylight hours over eastern Asia, and under darkness for the south-central Asia, including India, Sri Lanka and Pakistan. The Moon will next occult Aldebaran on August 16th, 2017. This is occultation 33 in the current series of 49 running from January 29th, 2015 to September 23rd, 2018. This is the second visible occultation of Aldebaran by the Moon post-solar conjunction on May 31st, 2017, and is well-placed for the Indian subcontinent.

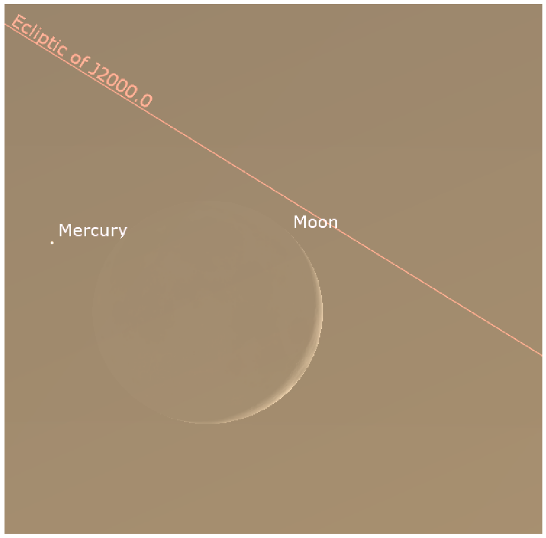
The view from India pre-occultation on July 20th. Image credit: Stellarium.
Aldebaran is the 14th brightest star in the sky and the brightest star that the Moon can occult currently.

Tuesday, July 25th: The Moon occults Mercury



The occultation footprint of Mercury by the Moon. Image credit Occult 4.2.
The 5% illuminated waxing crescent Moon occults the 54% illuminated, +1.1 magnitude planet Mercury. The Moon is 2 days past New during the event. Both are located 26 degrees west of the Sun at the time of the event. The central time of conjunction is 8:48 UT. The event occurs during the daylight hours over northern Asia and northern Europe and under darkness

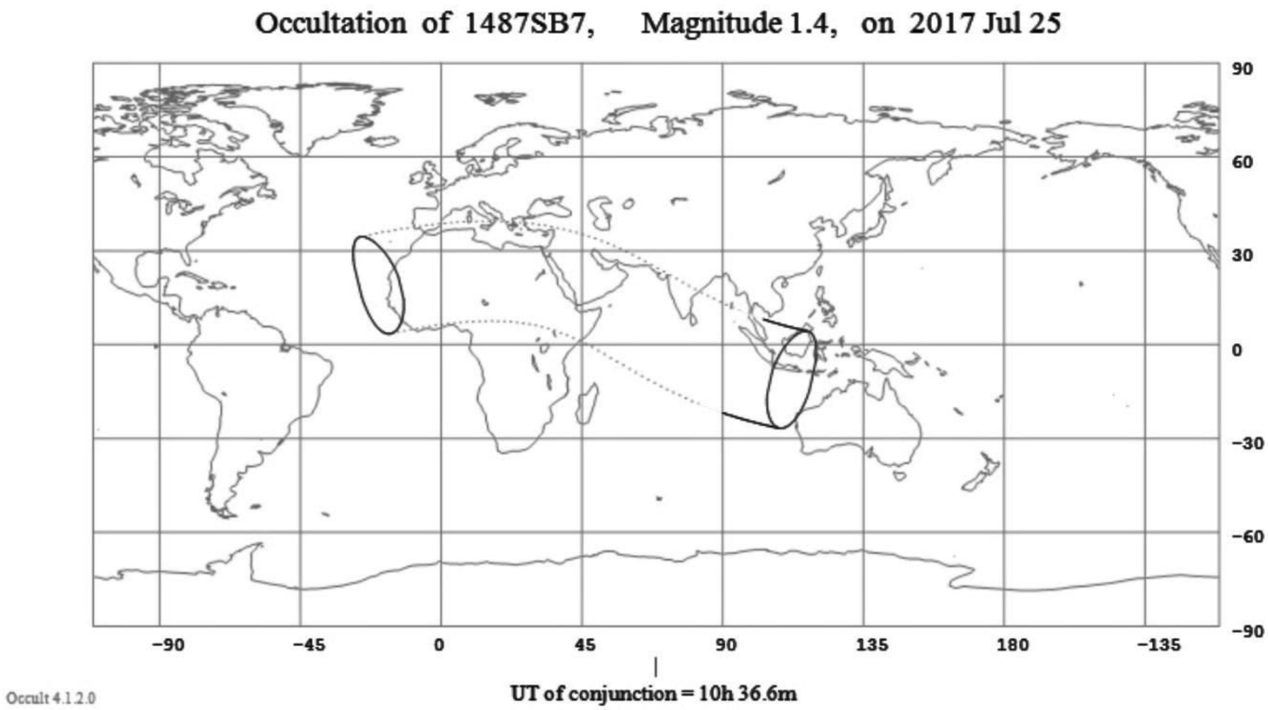
for northeast Asia, including Japan. The Moon will next occult Mercury on September 18th, 2017. Mercury is located 0.94 astronomical units (AU) or 141 million kilometers distant during the occultation. Mercury reaches greatest elongation 27 degrees west of the Sun five days after this occultation on July 30th.



The view from Japan just prior to the occultation. Image credit: Stellarium

With an equatorial radius of 2,440 kilometers, Mercury is actually 1.4 times larger than Earth's Moon.

Tuesday, July 25th: The Moon occults Regulus



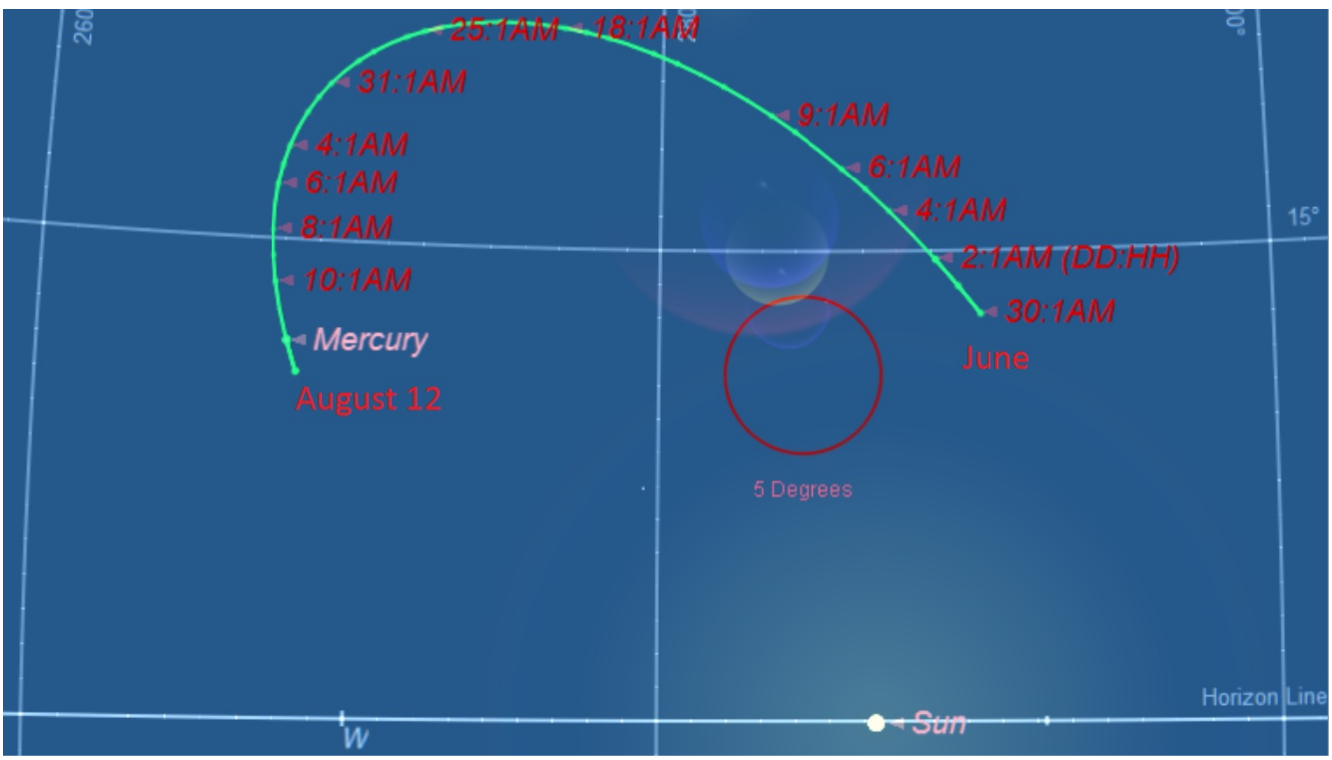
The occultation footprint for the July 25th event. Image credit Occult 4.2.

The 6% illuminated waxing crescent Moon occults +1.4 magnitude Regulus. The Moon is 2 days past New during the event. Both are located 27 degrees east of the Sun during the event. The central time of conjunction is 10:37 Universal Time (UT). The event occurs during the daylight hours over northern Africa, the Arabian peninsula and southern India and under darkness for southeast Asia, including Singapore, Indonesia and Malaysia. The Moon will next occult Regulus on August 21st, 2017. This is the 9th occultation in the current series of 19 running from December 18th, 2016 to April 24th, 2018. This occultation occurs while Regulus and Mercury are just a degree apart and is a near-simultaneous event (see the July 25th occultation of Mercury by the Moon over northeast Asia). This will create a unique 'smiling face' emoticon conjuction for observers around Singapore at dusk on July 25th:

The view on July 25th from Bali, Indonesia. Image credit: Stellarium.

The Moon simultaneously occulted Venus & Jupiter on April 23rd 1998 for Ascension Is. in the Atlantic.

Sunday, July 30th: Mercury reaches Greatest Elongation



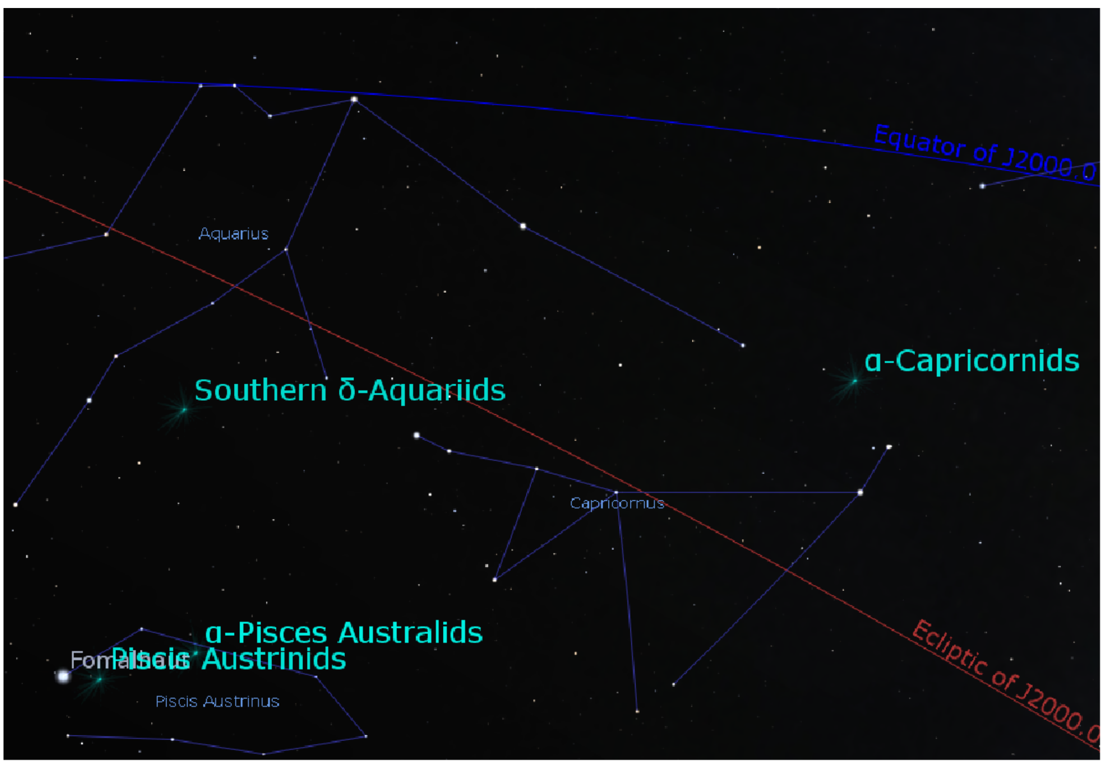
The path of Mercury from June 30th through August 12th, looking west from latitude 30 degrees north. Image credit: Starry Night Education Software.

The planet Mercury reaches greatest elongation 27 degrees east of the Sun in the dusk sky.

The exact hour of greatest elongation occurs on July 30th at 3:00 Universal Time (UT). Mercury is 7.8' in apparent diameter and presents a 46% illuminated disk at greatest elongation. This apparition of Mercury roughly favors both the northern and southern hemispheres. Mercury then begins to head back towards the Sun every evening until reaching inferior conjunction between the Sun and the Earth on August 26th. Mercury reaches theoretical dichotomy (half phase) on July 27th and a shines at a brilliancy of +1.3 magnitude at greatest elongation. Mercury will next reach greatest western (dawn) elongation on September 12th. This elongation of Mercury occurs just three days prior to reaching aphelion on August 3rd, and is the widest of the year.

On September 2016, analysis of data from NASA's MESSENGER spacecraft suggested that Mercury is tectonically active, and the shrinking planet may host periodic 'Mercury-quakes.'

Sunday, July 30th: The Delta Aquariids Meteor Shower



The location of the Southern Delta (δ) Aquariid meteor shower radiant. Credit: Stellarium.

The Delta Aquariid meteors are expected to peak on July 30th (peak variable and undefined), favoring southern hemisphere observers. The shower is active for a five week span from July 12th to August 23rd, and can vary with a Zenithal Hourly Rate (ZHR) of 15-30 meteors per hour. In 2017, the Delta Aquariids are expected to produce a maximum ideal ZHR of 25

meteors per hour. The radiant of the Delta Aquarids is located at right ascension 22 hours 35 minutes, declination -16 degrees south at the time of the peak, in the constellation of Aquarius.

The Moon is a 46% illuminated waxing crescent at the peak of the Delta Aquariids, making **2017 a favorable year** for this shower. In previous years, the Delta Aquariids produced a ZHR=30 (2014) and a ZHR of 40 (2009).

The Delta Aquariid meteors strike the Earth at a moderate velocity of 41 km/s, and produce many fireballs with an *r* value of 2.5. The source of the Delta Aquariids is believed to be an unnamed ancient stream of Kreutz sungrazing comets.

The Delta Aquariid meteors are sometimes divided into two close-moving northern and southern streams, the orbits of which bear a close resemblance to the June daytime Arietid meteors.

Edison's Chickens: A Weird West Tale and the Hunt for Vulcan

How the hunt for a planet that never was evolved into a modern day eclipse quest.

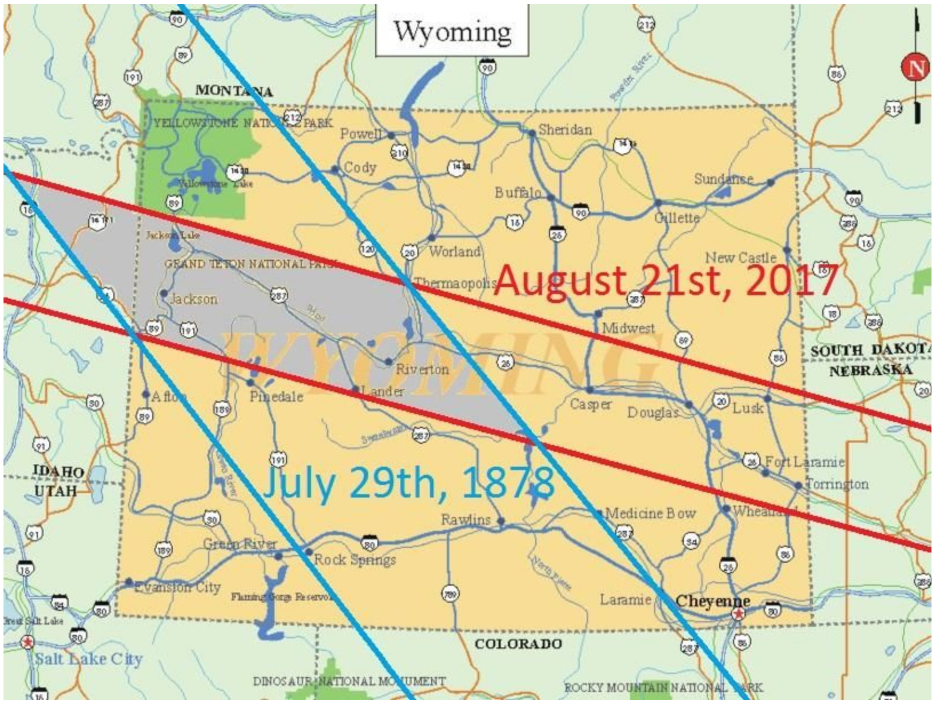
A solar eclipse over the Vehicle Assembly Building at the Kennedy Space Center.
Credit: David Dickinson.

How far would you go in the name of science? One of the most fascinating stories in astronomy involves a famous inventor, a rare celestial spectacle, and the pursuit of an enigmatic world.

August 21st, 2017 marks the return of totality to the contiguous United States, with a total solar eclipse spanning the country from coast-to-coast. Over 139 years ago, a similar eclipse drew American expeditions out to the Wild West.

The total solar eclipse of July 29th, 1878 offered a rare opportunity to witness the solar corona and probe the environs near the darkened solar disk. With a maximum totality of 3 minutes 11 seconds, this eclipse traced a path across western Canada and the United States, from the

territory of Montana to Louisiana.



The path of the 1878 vs 2017 total solar eclipse. Image credit: David Dickinson.

A curious band of astronomers were also waiting for the approach of the Moon's shadow, searching for an elusive world known as Vulcan. Long before *Star Trek* or Mr. Spock, Vulcan was a hypothetical world thought to inhabit the region between the planet Mercury and the Sun.

The tale of Vulcan is the story of the birth of modern predictive astronomy. Vulcan was a reality to 18th century astronomers – it can be seen gracing the astronomy textbooks and contemporary art and culture of the day. French astronomer and mathematician Urbain J.J. Le Verrier proposed the existence of the planet in 1859 to explain the anomalous precession of the perihelion of the planet Mercury. Le Verrier was a voice to be taken seriously — he had performed a similar feat of calculation that led observers to discover the planet Neptune from the Berlin Observatory on the night of September 23, 1846. Almost overnight, Le Verrier's mathematical insight vaulted astronomy into the realm of a science with real predictive power.

The idea of Vulcan gained traction when the French doctor and amateur astronomer Edmond Lescarbault claimed to have seen the tiny world transit the Sun while viewing it through his 95 millimeter refractor on the sunny afternoon of March 26th, 1859. Keep in mind, this was during an era when solar observations were carried out via the hazardous method of viewing the Sun through a smoked glass lens or an oil-filled filter, or by occasionally using the safer technique of projecting the disk of the Sun through a telescope onto a piece of paper or into a darkened room and sketching what the observer saw.

A visiting Le Verrier was sufficiently impressed by Lescarbault's find and published orbital

tables of Vulcan based on his own calculations. Soon, astronomers everywhere were seeing dots pass in front of the Sun. Astronomer F.A.R. Russell spotted an object transiting the Sun while observing from London on January, 29th, 1860. Sightings continued over the decades, including a claim by an observer based near Peckeloh, Germany who witnessed a transit of Vulcan on April 4th, 1876. Incidentally, we are not immune the psychological phenomenon of 'contagious observations' today. For example, when Comet Holmes brightened to naked eye visibility in October 2007, spurious reports of *other* comets brightening soon flooded message boards. A similar occurrence proceeded amateur astronomer Anthony Wesley's observation of an impact on Jupiter in 2010, prompting sporadic reports of other anomalous spots appearing on other worlds. Though the initial events that triggered them were real, the claims of impacts on other bodies in the solar system were all bogus.

Still, reports of the planet Vulcan were substantial enough for astronomers to mount an expedition to the territory of Wyoming in an attempt to catch the fleeting world near the Sun during the brief moments of totality. Participants included Simon Newcomb of the Naval Observatory, James Craig Watson and Lewis Swift. Inventor Thomas Edison also made the trip to Rawlins, Wyoming hoping to test his new-fangled tasimeter in an effort to measure the heat of the solar corona.

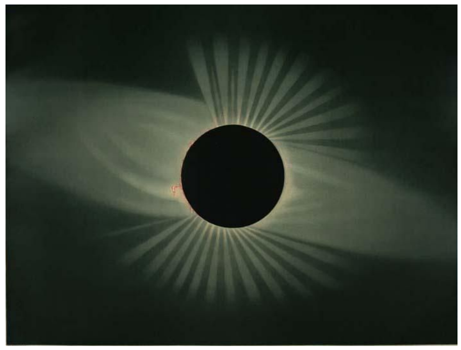
Astronomers from the Royal Astronomical Society and Princeton ready for the eclipse near Denver, Colorado. Credit: Public Domain image.

Conditions were austere, to say the least. Edison blew into town late and, like many last minute eclipse-chasers before and since, found no room at the inn. In his later memoirs, he recalls finally finding lodging above a local saloon, where his celebrity drew the attention of a local gunslinger who, bursting in to Edison's room inebriated, identified himself as 'Texas Jack,' and sought to impress a surprised Edison with his sharp-shooting prowess.

But such are the travails of eclipse-chasing. Although the teams endured dust storms that nearly threatened to cut their expeditions short, the morning of eclipse day on the 29th

dawned, as one newspaper reported, “as slick and clean as a Cheyenne free-lunch table.” Totality began just after 4:00 PM local, as observers deployed near the tiny town of Separation, Wyoming swung their instruments into action.

Now, such a quest is difficult under the best of circumstances. Observers had to sweep the area within three degrees (six times the diameter of a Full Moon) near the eclipsed Sun quickly using only narrow-field refractors, all while looking for a star +4th magnitude or fainter among the established star fields.



A rendering of the 1878 total solar eclipse as seen from Creston, Wyoming by Étienne Léopold Trouvelot... perhaps depicting shadow bands? Image in the Public Domain.

In the end, the expedition was both a success and a failure. Watson and Swift both claimed to have identified a +5th magnitude object similar to the nearby star Theta Cancri. Astronomer Christian Heinrich Friedrich Peters later cast doubt on the sighting and the whole Vulcan affair, claiming that “I refuse to go on a wild goose chase after Le Verrier’s mythical birds!”

Meanwhile, back in Rawlins, inventor Thomas Edison fared little better. One thing Edison did not count on was the onset of dusk-like conditions as totality approached. As skies darkened and Edison aimed his tasimeter skyward, he encountered another eclipse phenomenon when chickens, fooled by the approaching false dusk, came home to roost at the onset of totality, overrunning the surprised inventor. Ultimately, Edison's device proved to be too sensitive, and the temperature of the corona went unmeasured.

But again, such is the life of an eclipse-chaser. In 1916, Albert Einstein’s general theory of relativity explained the precession of Mercury’s orbit and did away with a need for Vulcan entirely...

But is the idea of intra-Mercurial worldlets down for the count?

Amazingly, the quest for objects inside Mercury’s orbit goes on today, and the jury is still out. Dubbed *Vulcanoids*, modern day hunters still probe the inner solar system for tiny asteroids that may inhabit the region close to the Sun. In 2002, NASA conducted a series of high altitude flights out of the Dryden Flight Research Center at Edwards Air Force Base,

California, sweeping the sky near the for Vulcanoids at dawn and dusk. Now, there's a job to be envious of: an F-18 flying astronomer!

NASA's MESSENGER spacecraft was also on the lookout for Vulcanoids on its six year trek through the inner solar system prior to orbital insertion on March 18th, 2011. It also came up empty-handed.

Thus far, all these hunts have turned up naught. But one of the most fascinating quests is still ongoing, and led by veteran eclipse chaser Landon Curt Noll. Mr. Noll conducted a sweep for Vulcanoids during total phases of the long duration total solar eclipse of July 22nd, 2009 across the Far East. He uses a deep sky imaging system, taking pictures in the near-infared to accomplish this search.

Using near-infrared imaging during a total solar eclipse requires a stable platform, meaning that performing this feat at sea or even via an airborne platform such as NASA's SOFIA flying observatory is out. Such a rig has been successful at catching the extremely thin crescent Moon at the moment it reaches New phase near the Sun. Mr. Noll also notes that the European Space Agency's Solar Heliospheric Observatory (SOHO) spacecraft has, for all intents and purposes, eliminated the possibility of Vulcanoids brighter than +8th magnitude near the Sun. Modern searches during eclipses conducted in this fashion scan the sky between wavelengths of 780 to 1100 nanometers down to magnitude +13.5. "Our improved orbital models show that objects as small as 50 meters in diameter could reside in a zone 0.08 A.U. to 0.18 AU (1.2 to 2.7 million kilometers) from the Sun," says Noll. "There is (still) plenty of 'room' for (Vulcanoids) in the 50 meter to 20 kilometer range."

This year, Mr. Noll plans to resume his hunt for any possible Vulcanoids during the August 21st, 2017 total solar eclipse spanning the continental United States. His plans are to observe from Jackson Hole, Wyoming, where totality for this eclipse will be a maximum duration of 2 minutes and 16 seconds.

The quest for Vulcan (or at least Vulcanoids) is alive and well and being spearheaded by adventurous and innovative amateur astronomers. In the words of Vulcan's native fictional son, may it "Live Long & Prosper!"

-For a fascinating read on the subject, check out *In Search of planet Vulcan* by Richard Baum and William Sheehan.

-Read more of Mr. Noll's fascinating article *Searching for Vulcanoids:*
http://www.isthe.com/chongo/tech/astro/SandT-200805-vulcanoid_v3.pdf

Other sources:

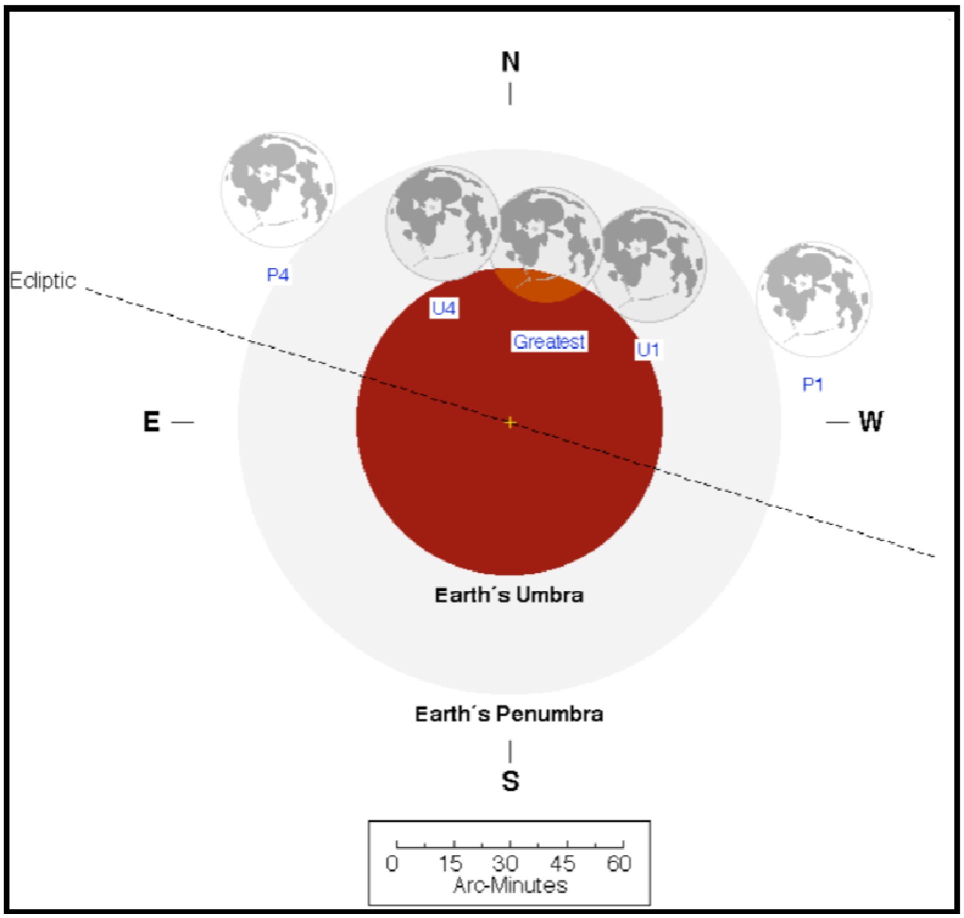
-*Eclipse Vissitudes: Edison and the Chickens* by J. Donald Fernie (American Scientist):
http://www.americanscientist.org/issues/pub/2000/3/eclipse-vicissitudesthomas-edison-and-the-chickens

-*The Great American Eclipse*, Michael Zeiler;
http://www.greatamericaneclipse.com/19th-century/

-*Edison, the Light Bulb and the Eclipse of 1878* by Phil Roberts:
http://www.wyohistory.org/encyclopedia/edison-light-bulb-and-eclipse-1878

August 2017

Monday, August 7th: A Partial Lunar Eclipse

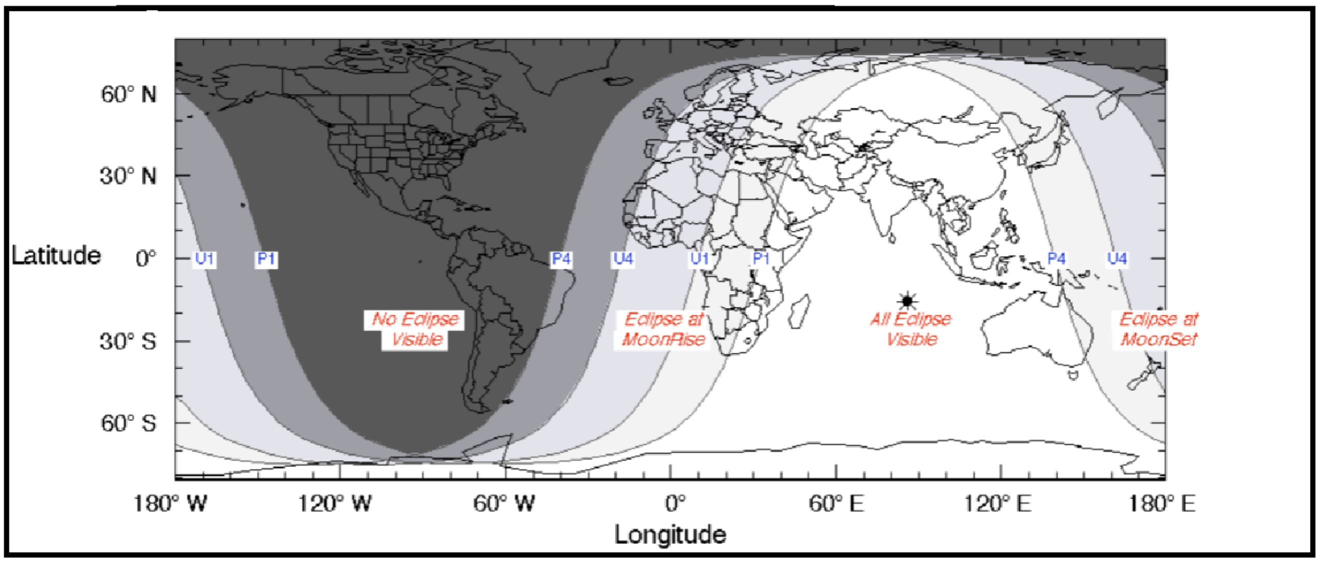


The path of the Moon through Earth's shadow.
Image credit: NASA/GSFC/F. Espenak.

The Moon passes through the inner umbral edge of the Earth's shadow from 17:23 to 19:21

Universal Time (UT). This is the **second lunar eclipse for 2017**. This a penumbral and a partial umbral eclipse, with the Moon 25% immersed in the Earth's inner shadow at 18:21 UT. The eclipse is visible in its entirety from the Indian Ocean region. The eclipse occurs at moonrise for western Africa and Europe, and moonset for eastern Australia and the Far East. This eclipse is member 62 of 83 for saros series 119, which began on October 14th 935 AD and ends on March 25th 2396. This saros produced its last total lunar eclipse on July 28th, 1999. The next lunar eclipse is the final partial in lunar saros 119 on August 19th, 2035.

This lunar marks the start of the second eclipse season for 2017 and is the final eclipse — lunar or solar — prior to the total solar eclipse crossing the contiguous United States two weeks later on August 21st.



The visibility prospects for the August 8th lunar eclipse. Image credit: NASA/GSFC/F. Espenak.

On May 22nd, 1453, a rising partial lunar eclipse over the besieged city of Constantinople preceded the city's fall to the Ottoman Turks by seven days, as foretold by prophecy.

Partial Eclipse by Christopher Jivanka. https://www.instagram.com/gamma_neo/

Saturday, August 12th: The Perseid Meteor Shower

The radiant of the Perseid meteor shower versus the waning gibbous Moon on August 12th. Credit: Stellarium.

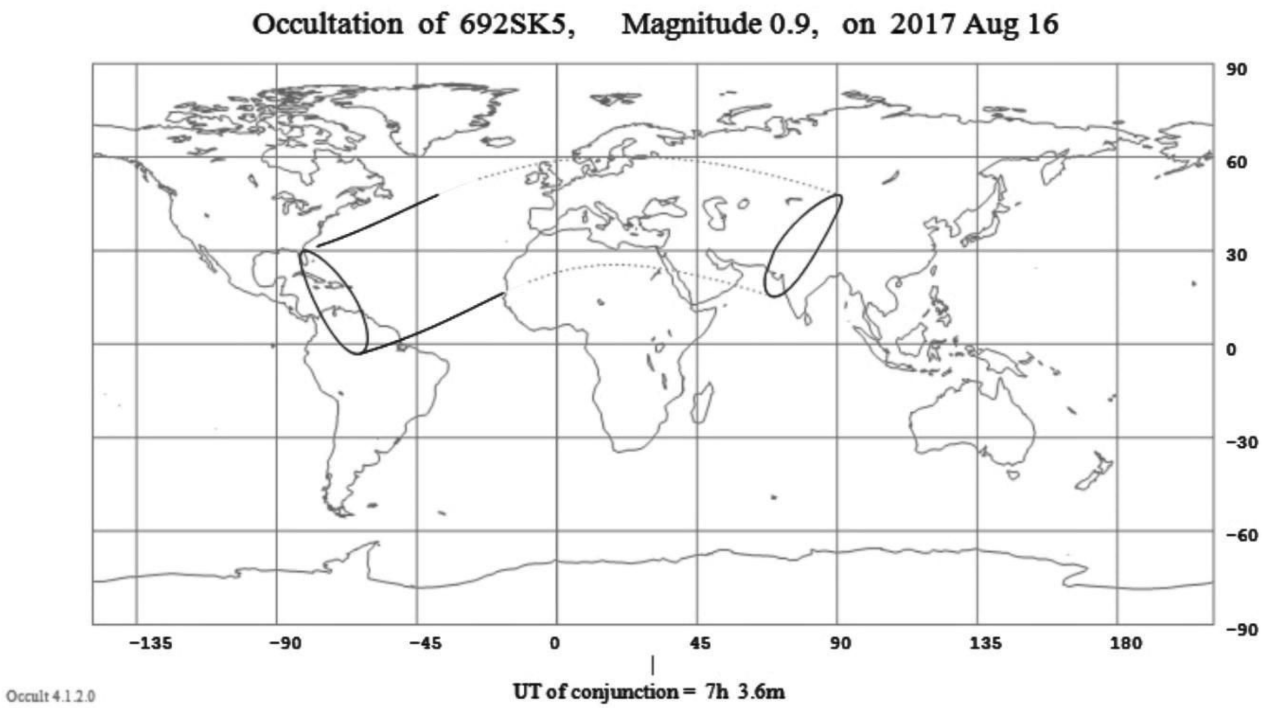
The Perseid meteors are expected to peak on August 12th, with a broad peak favoring northern hemisphere viewers worldwide. The shower is active for a five week span from July 17th to August 24th, and can vary with a Zenithal Hourly Rate (ZHR) of 100-200 meteors per hour. In 2017, the Perseids are expected to produce a maximum ideal ZHR of 150 meteors per hour. The radiant of the Perseids is located at right ascension 3 hours 4 minutes, declination +58 degrees north at the time of the peak in the constellation of Perseus.

The Moon is a 81% illuminated waning gibbous at the peak of the Perseids, making **2017 an unfavorable year** for this shower. In previous years, the Perseids produced a Zenithal Hourly Rate (ZHR) of 117 (2016) and a ZHR of 95 (2015).

The Perseids meteors strike the Earth at a moderate velocity of 59 km/s, and produce many fireballs with an *r* = 2.2. The source of the Perseids is Comet Swift-Tuttle.

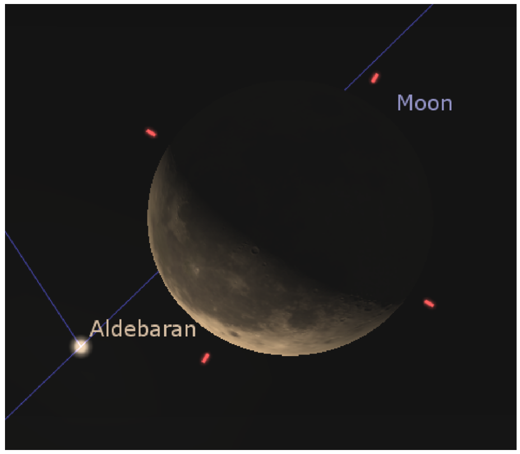
One of the more dependable annual meteor showers, the Perseids are sometimes referred to as the “Tears of St. Lawrence,” after the saint who was martyred on a hot gridiron on August 10th, 258 AD.

Wednesday, August 16th: The Moon occults Aldebaran



The occultation footprint for the August 16th event. Image credit: Occult 4.2.

The 36% illuminated waning gibbous Moon occults the +0.9 magnitude star Aldebaran. The Moon is six days from New during the event. Both are located 74 degrees west of the Sun at the time of the event. The central time of conjunction is 7:04 Universal Time (UT). The event occurs during the daylight hours over Europe and the Mediterranean region, and under darkness for the the western Atlantic, including northeastern South America and the eastern Caribbean. The Moon will next occult Aldebaran on September 12th. This is occultation 34 in the current series of 49 running from January 29th, 2015 to September 23rd, 2018. The occultation is well placed for observers in Europe and the United Kingdom to nab Aldebaran near the Moon under daytime skies.

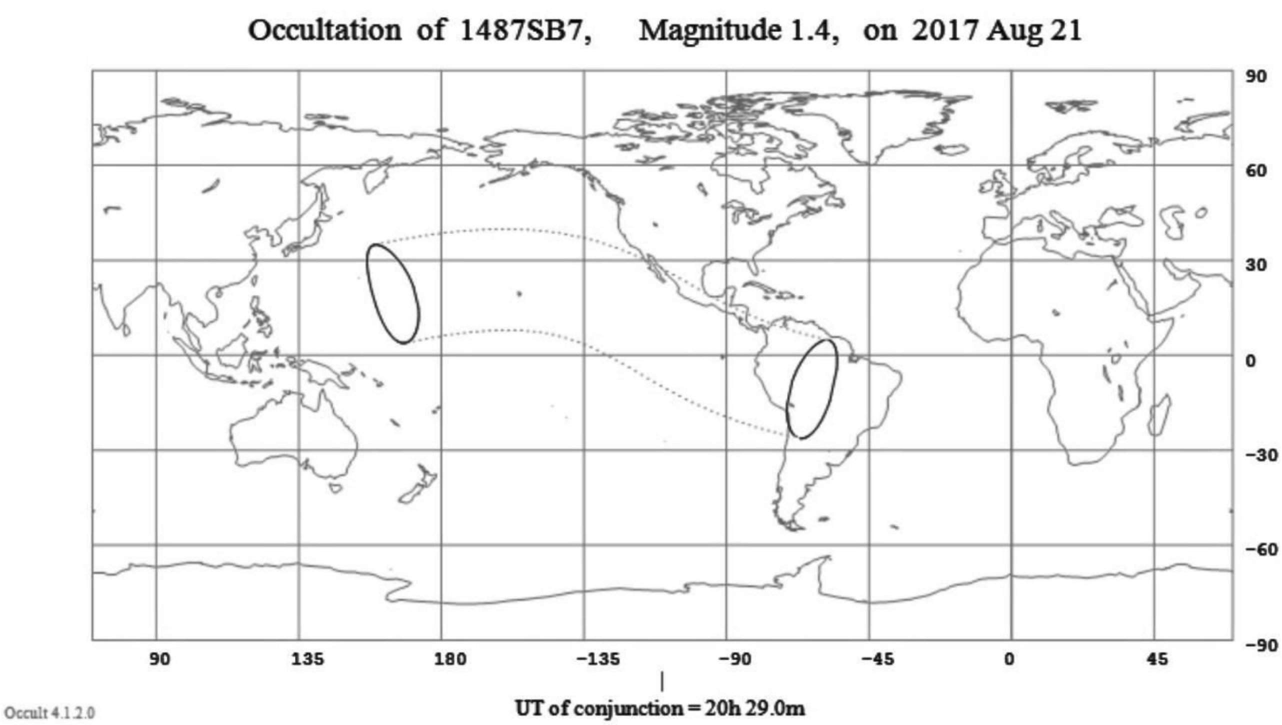


The view on September 16th as seen from the eastern Caribbean. Image credit: Stellarium.

The bright illuminated limb of the Moon always leads its path during an occultation when the Moon is waning, and the dark limb leads when the Moon is waxing.

Monday, August 21st: The Moon occults Regulus

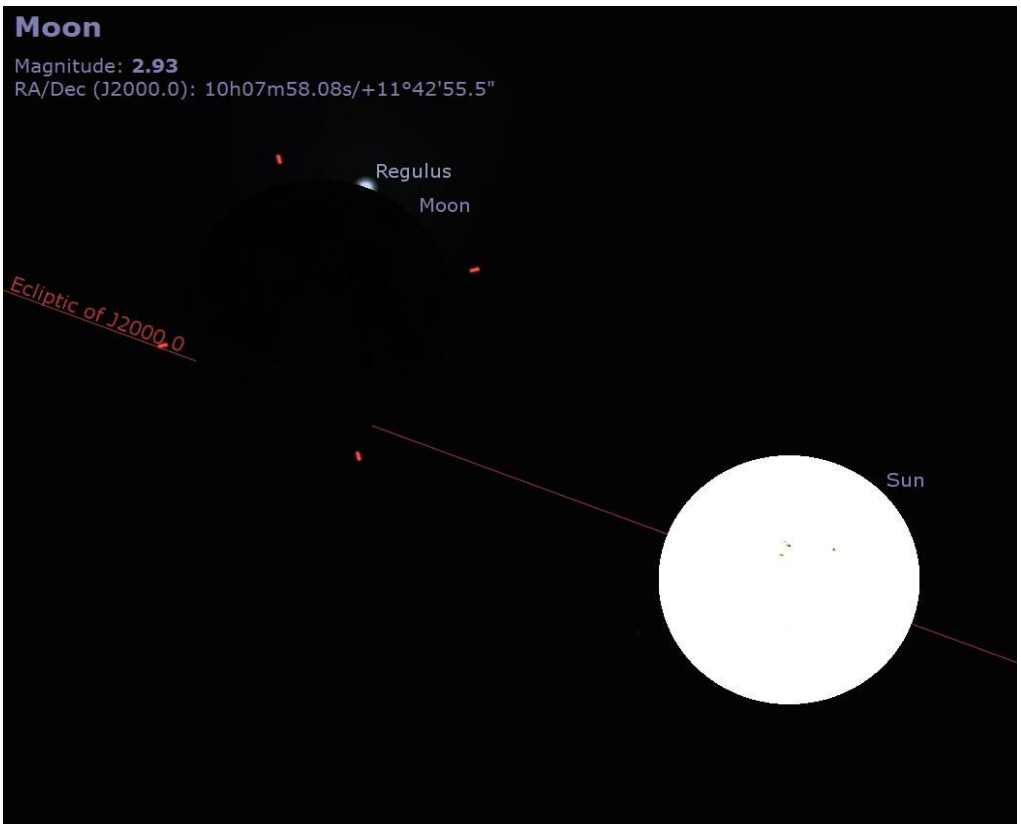
WARNING: never attempt to observe a star, Moon or planet near the Sun. Unlike other entries in this guide. This entry is of academic interest only.



The footprint for the August 21st event. Image credit: Occult 4.2.

The 0.01% illuminated waxing crescent Moon occults the +1.4 magnitude star Regulus. The Moon is one hour and 52 minutes past New during the event. Both are located just over one degree east of the Sun at the time of the event. The central time of conjunction is 20:29 Universal Time (UT). The event occurs during the daylight hours over southern central America and northwestern South America and across the central Pacific, including Hawaii. The Moon will next occult Regulus on September 18th, 2017. This is occultation 10 in the current series of 19 running from December 18th, 2016 to April 24th, 2018.

This occultation occurs shortly after the total solar eclipse (see the following entry) spanning the contiguous United States just to the north. Though the event is unobservable due to its proximity to the Sun, it is included here because of its connection with the historic total solar eclipse on the same day.

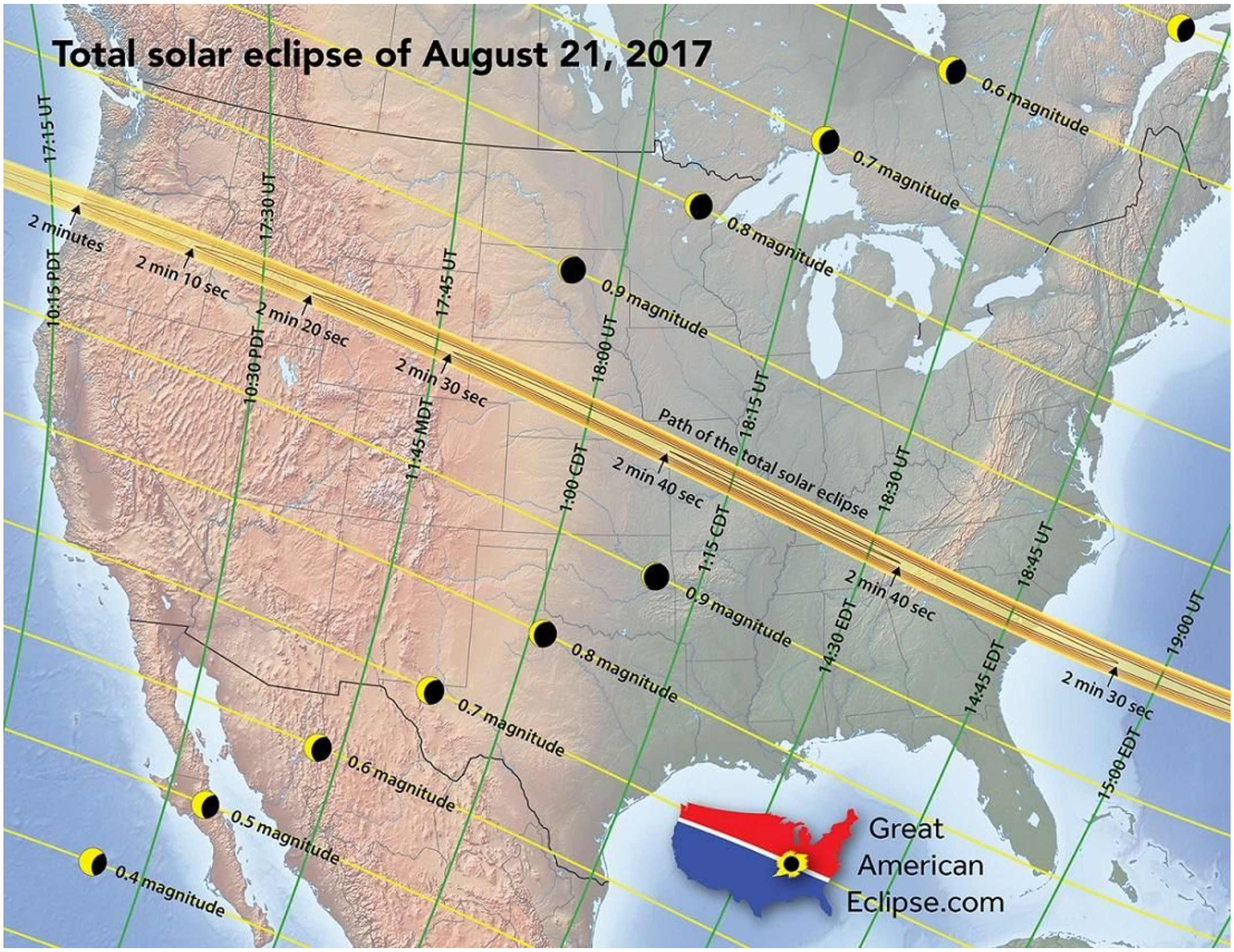


The view on August 21st from Baja California. Image credit: Stellarium.

On July 8th 2013, astrophotographer Thierry Legault caught a razor thin Moon just 4.4 degrees from the Sun... at the moment it passed New phase. He used a specially designed sun-shield and a camera equipped with an infrared low pass filter for the amazing capture:

http://www.universetoday.com/103341/incredible-astrophoto-the-youngest-possible-new-moon-by-thierry-legault/

Monday, August 21st, 2017: A Total Eclipse of the Sun



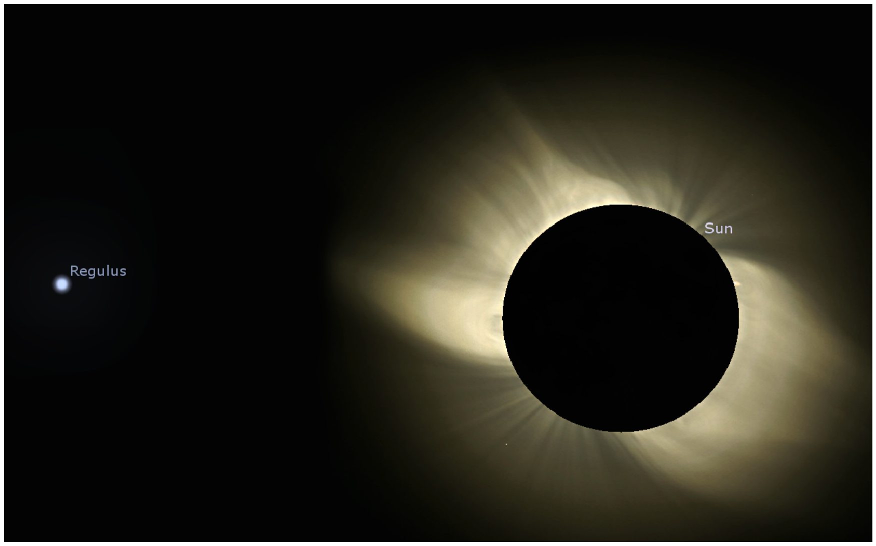
The path of the eclipse over the contiguous 'lower 48' states.
Image credit: Michael Zeiler/www.The GreatAmericanEclipse.com.

A total solar eclipse of the Sun occurs. After more than 38 years, totality returns to the continental (contiguous) United States, as a total solar eclipse spans the country from coast to coast. This eclipse is the first time that totality has touched the continental U.S. since February 26th, 1979. The last time an eclipse spanned the U.S. coast in the same fashion was back in June 8th, 1918.

After an 'eclipse drought,' North America will once again host *another* total solar eclipse just under seven years later, crisscrossing the United States from the southwest to the northeast on April 8th, 2024.

The action begins on the morning of Monday, August 21st, as partial phases begin at 15:47

Universal Time (UT). The umbra (dark inner shadow) of the Moon touches down along the Oregon coast at 17:16 UT/10:16 AM PDT Pacific Time, and races eastward at 3,900 kilometers per second.



The moment of totality, plus scenes from the eclipse. Note that the bright star Regulus sits just one degree away from the limb of the Moon during mid-eclipse!

The path of totality will cross Oregon, Idaho, Wyoming, Colorado, Nebraska, Kansas, Missouri and Illinois, where it will reach a greatest totality of 2 minutes 40 seconds in duration for latitude 37.58 degrees north, longitude 89.11 degrees west, just outside of the city of Carbondale, Illinois. From there, the eclipse will head southeast through Tennessee, Kentucky, North Carolina and South Carolina before leaving land along the South Carolina coast at 18:48 UT/2:48 PM EDT and headed out across the Atlantic Ocean, leaving the surface of the Earth at 20:03 UT. The partial phases of the eclipse end at 21:04 UT.

The Illinois, Kentucky, Missouri tri-state region actually witnesses *two* eclipses in the span of 8 years.

Safety is paramount during the partial phases of any solar eclipse. Use only eclipse glasses designed for solar observing, but by all means, lower those glasses during totality, to witness the pearly white corona of the eclipse and perhaps a prominence or two, leaping off the limb of the Sun. A great resource for eclipse safety is www.mreclipse.com.

Millions live within a days drive of the eclipse, and it happens in the middle of summer camping season to boot... this total solar eclipse may well be the most witnessed in all of history.

For saros buffs, this eclipse is number 22 of 77 eclipse in saros 145, which began on January 4th, 1639, and ends on April 17th, 3009 AD. This saros produced its first total solar eclipse on June 29th 1927 and will produce its final of 41 total solar eclipses on May 4th, 2096. If you saw

the August 11th, 1999 total solar eclipse, then you caught the last eclipse in the same saros. The next one occurs on September 2nd, 2035.

Until the advent of photography, a debate raged as to whether prominences seen during an eclipse were from the Sun, or due to volcanic activity on the Moon. Charles Draper settled this argument on July 29th 1878, when he captured the first images of totality, demonstrating the flares are indeed solar based.

Monday, August 21st: A Black Moon

A Black Moon occurs on August 21st, 2017, with the advent of the New Moon at 18:32 Universal Time (UT). Like the 'Super' or 'Mini' Moon, this is more of a modern day cultural meme than a true astronomical event. The older reference to a Blue Moon comes down to us from the *Maine Farmer's Almanac* in the early half of the 20th century, and, strangely, is used to denote the 'third Full Moon in an astronomical season with four.' The simpler and more commonly used modern meaning comes from an error in a 1946 edition of *Sky & Telescope* magazine, as the second Full Moon in a calendar month with two. Likewise, a 'Black Moon' follows similar rules for the Moon at New phase. This month's Black Moon falls under the 1st rule, as the third in an astronomical season with four. The season breaks down as follows:

June northward solstice: June 21st
New Moon 1: June 24th
New Moon 2: July 23rd
New Moon 3: August 21st
New Moon 4: September 20th
September southward equinox: September 22nd

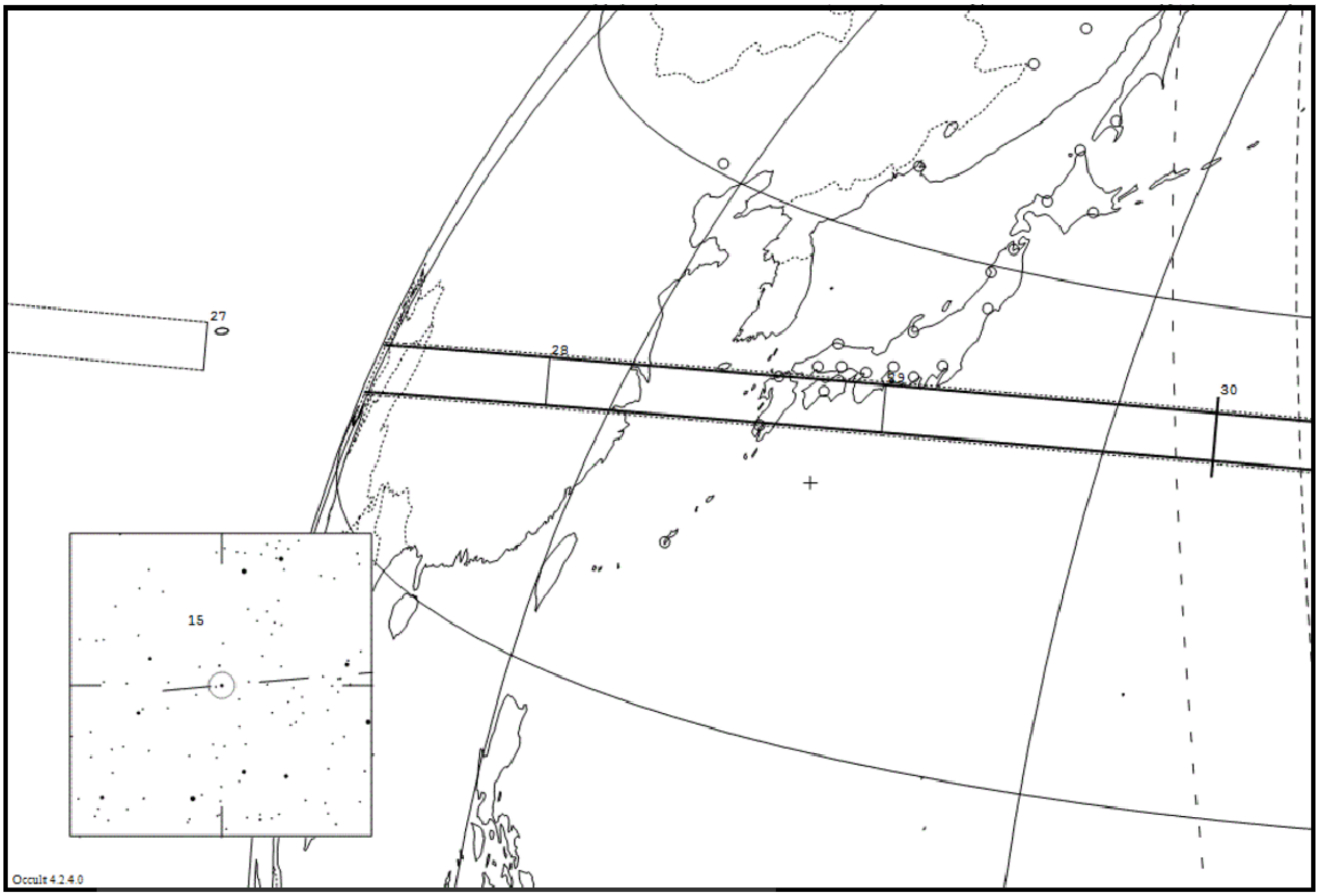
Year	Date	Type	3rd of 4*	2nd in a Month	Notes
2012	August 31st	Blue	-	Y	
2013	August 21st	Blue	Y	-	
2014	January 30th	Black	-	Y	
2014	February	Black	-	-	Missing a New Moon
2014	March 30th	Black	-	Y	
2015	February 18th	Black	Y	-	
2015	July 31st	Blue	-	Y	
2016	May 21st	Blue	Y	-	
2016	Oct 30th	Black	-	Y	
2017	August 21st	Black	Y	-	Total Solar Eclipse
2018	January 31st	Blue	-	Y	Total Lunar Eclipse
2018	February	Black	-	-	Missing a Full Moon
2018	March 31st	Blue	-	-	
2019	May 18th	Blue	Y	-	
2019	August 30th	Black	-	Y	
2020	August 19th	Black	Y	-	
2020	October 31st	Blue	-	Y	Halloween

Black and Blue Moons using various conventions through to 2020.

The next Black Moon in the sense of a 'month missing a New Moon' occurs in February 2018. February is the only month short enough to miss a phase (i.e., New, Full, etc) entirely.

Of course, this New Moon is also special, and much more well known for the August 21st, 2017 Great American total solar eclipse spanning the contiguous United States (see previous entry). Solar eclipses, by default, must occur at New Moon, a fact often skipped in fictional depictions of eclipses. Will the 2017 eclipse also gain notoriety for the strange attribute of being part of an 'old timey' definition as a Black Moon as well? The next Black Moon solar eclipse (a partial) occurs on April 30th, 2022.

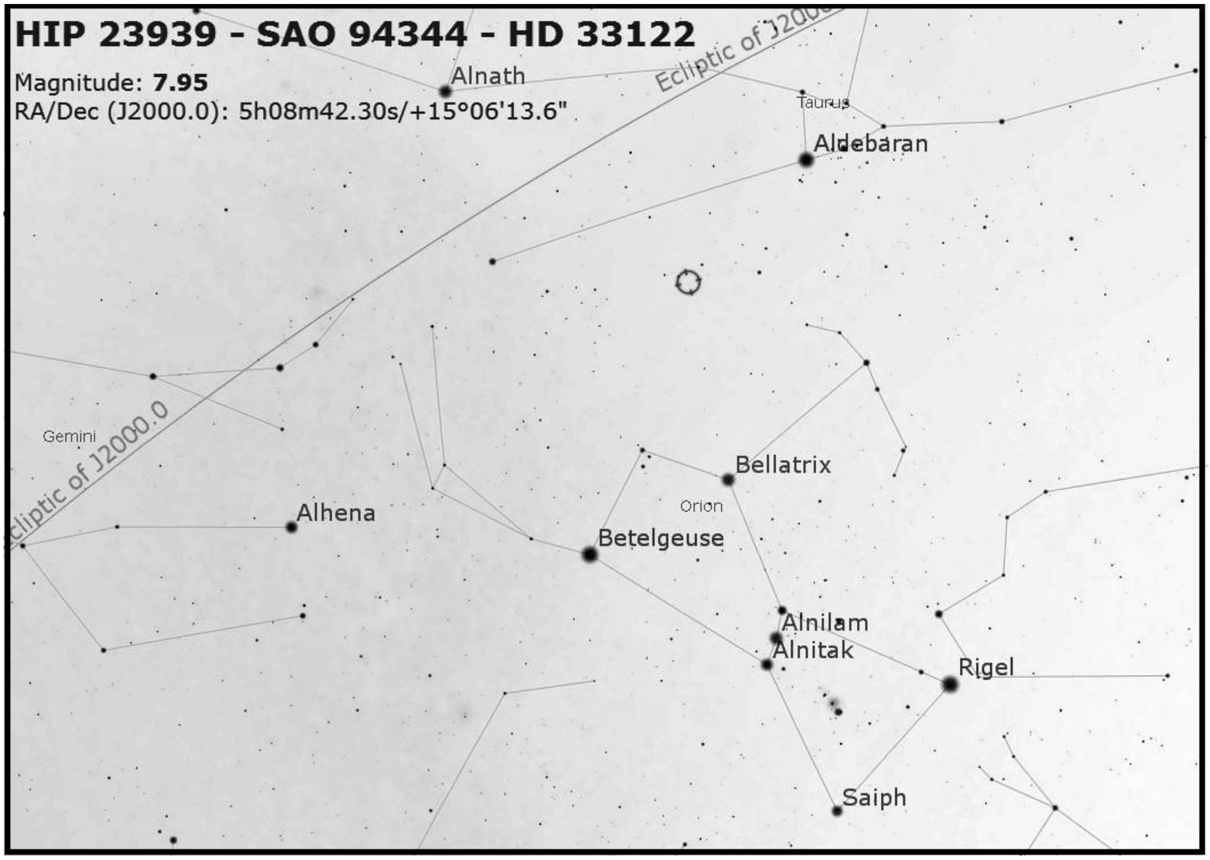
Tuesday, August 29th: Asteroid 59 Elpis occults a +8 magnitude star



The path of the occultation of SAO 94344 by 59 Elpis. Image credit: Steve Preston/Occult 4.2.4.0.

Asteroid 59 Elpis occults the +8th magnitude star SAO 94344. The 213 kilometer wide path crosses the Earth from 18:27 to 18:36 Universal Time (UT). The occultation path crosses Japan and China around 18:29 UT, including the island of Kyushu. The asteroid's brightness is magnitude +13 at the time of the event, and the occultation should last 9 seconds in maximum duration as seen from the center line. The probability rank for this event is 100%. The Moon is 54% waning gibbous during the event. The occulted star is located in the constellation Orion. As seen from Kagoshima, Japan, the occultation occurs under darkness and is 40 degrees above the horizon. Solar elongation for the occultation is 79 degrees, and the maximum expected magnitude drop is 5.

Orbiting the Sun once every 4.5 years, NASA has pinged 59 Elpis on occasion. It is known to be about 165 kilometers on its longest axis.



A finder chart for SAO 94344. Image credit: Stellarium.

Discovered on the night of September 12th, 1860 by French astronomer Jean Chacornac, 59 Elpis was at the center of a brief controversy as to whether the growing number of asteroids should continue to receive mythological names or, like comets, get named after their discoverers. The Greek personification of Hope, Elpis was the last remaining deity remaining in Pandora's Box when the lid was slammed shut. The name was suggested by astronomer Karl Littrow to reflect a then peaceable Europe. Today, asteroids names are submitted by the discoverer to the International Astronomical Union and include authors, rock stars and celebrities.

On Moons, Black and Blue

The lunacy of modern memes.

Blue Moon zaniness... (photo by author).

It's strange what astronomical events capture the public consciousness sometimes. Every few years, articles breathlessly re-report the 'discovery' of Ophiuchus the Serpent Bearer and herald it as the 13th constellation of the zodiac, giving the astrologically-minded pause as they whether they may in fact actually be snake-carrying Ophiuchians. Then there's the yearly rounds made by the Full perigee Supermoon, a Proxigean Full Moon that always seems to fail to wreak havoc for yet another year. And again, science bloggers shake their collective heads as they dust off last year's post on how the Moon reaches perigee nearly as close every lunation, or the precession of the equinoxes isn't really a new discovery, etc…

And yet, we're drawn almost lemming-like to write about these non-stories that always send

our Search Engine Optimization numbers surging. Hey, it's a teachable moment, right? And we're just as thrilled as anyone at the opportunity to get eyes on the sky, or at least explain to anyone willing to listen just how cool the universe *really* is.

Such is the case with this year's New Moon, occurring on Monday, August 21st at 18:32 Universal Time (UT). Being the 3rd New Moon in a season with four, this has entered the modern vernacular as a 'Black Moon,' albeit in a convoluted, old-timey sense. Not that its at all very rare, unless you count the fact that it coincides with a total solar eclipse.

None More Black (and Blue)

Now, *seeing* the Full Moon appear visually Blue is indeed rare, unless you happen to live near a sulfur-spewing factory. Such a spectacle occurred worldwide in 1883 after the eruption of Krakatoa. Observers in India also spied visually blue Moon caused by suspended atmospheric dust in 1927. In 1951, forest fires in western Canada also caused the Moon to take on a bluish cast as seen from the U.S. northeast. I've yet to see a convincing photograph of such a phenomena, though you'd think one would turn up, with the advent of mobile phone cameras deployed across the globe.

The controversy surrounding the modern definitions of a Blue Moon and how the term 'Black Moon' worked its way into the story is a fascinating tale of modern astronomy as culture.

The idea that a Blue Moon is the second Full Moon in a calendar month with two stemmed from an error in the March 1946 edition of *Sky & Telescope*, and was explored in their March 1999 edition. The original definition of a Blue Moon as laid out by the 1937 *Maine Farmers Almanac* is even more Byzantine, as "the 3rd Full Moon in a season with 4". Seasons (from equinox to solstice, and vice versa) are on average 91.3 days long, and 3 lunations (equal to 4 Full Moons) are about 29.5 x 3= 88.5 days in length, so you've got not quite three days of wiggle room for ye' ole Blue Moon of your grand-pappy's day to occur. Legend has it that the 'Blue' refers to the ink used to mark the extra superfluous moon on those tables of yore... any old Maine Farmers Almanacs kicking around in the attic out there to confirm this legend?

So, what's the practical upshot of a Blue Moon? What significance do you assign to these online astro-neophytes arriving at your cyber doorstep, eager for all things indigo? Well, there's nothing amazing to see, other than a regular old Full Moon hanging in the sky. The Full Moon will rise in the east at local sunset, 'unblued' just like it did at the beginning of the month. The phenomena of a Blue Moon is merely an artifact of our solar-based Gregorian Calendar; all months except February are longer than the lunar synodic period, and thus can have the same phase twice.

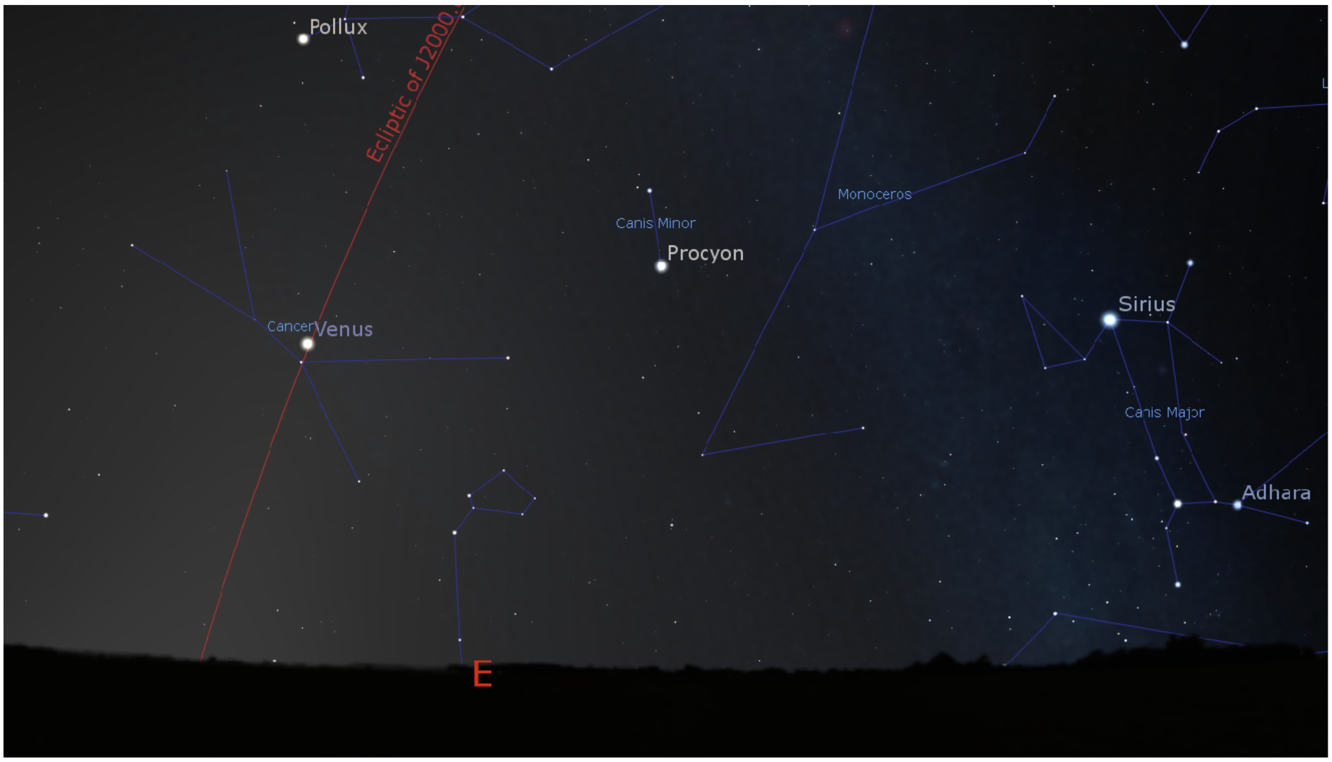
Incidentally, the term 'Black Moon' has come into vogue in recent years, as if astronomy writers don't have enough bizarre non-events in our lives. Think of a Black Moon as a Blue Moon's New Moon counterpart. In addition, a Black Moon also has the superpower of referring to a February devoid of a Full or New Moon, the only month on which this can occur. So is a February on a leap year minus a Full or New Moon a 'Super-Black Moon?' Or how

about a Black Moon Eclipse, as happens this year? Do we even need to go there?

Love ‘em or hate ‘em, colorfully named lunations of all stripes are here to stay.

September 2017

Friday, September 1st: Zodiacal Light Season Begins



The zodiacal light along the ecliptic versus the Milky Way as seen from latitude 32 degrees north on September 1st at dawn. Image credit: Stellarium

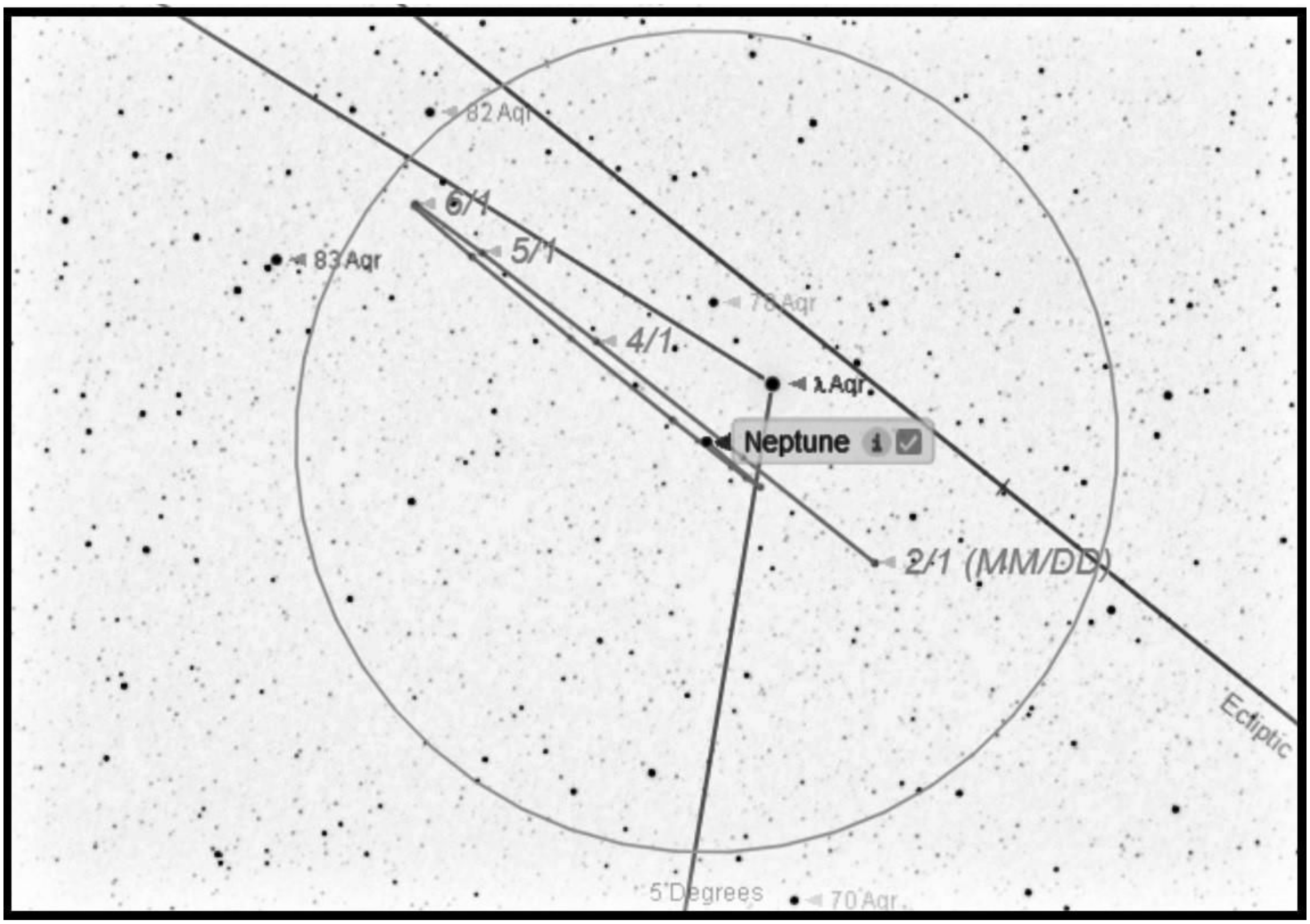
Zodiacal light season begins, as the Sun approaches the September (southward equinox) on September 22nd. This is a back-scattering of light off of dust particles spread out along the ecliptic plane. Spring and Fall are the best times to see this pearly glow in the dawn or dusk. This is because of the steep angle of the ecliptic relative to the horizon. The September equinox season favors dusk for the southern hemisphere, and dawn for the northern hemisphere; the reverse is true near the March equinox.

To see the zodiacal light, start your vigil around an hour after sunset or an hour before dawn, and observe from as dark a site as possible. Any light pollution or faint glows from distant cities on the horizon can kill the ethereal glow. The zodiacal light will appear as a slender pyramid-shaped glow, tracing the length of the ecliptic plane.

Sometimes referred to as a 'false dawn,' the zodiacal light can extend all the way to the horizon from a truly dark location.

The Apollo 15 mission to the Moon was tasked with observing the elusive counter-glow related to the zodiacal light (known as the *gegenschein*) while the Command Module was it the shadow of the Moon. The effort was unsuccessful.

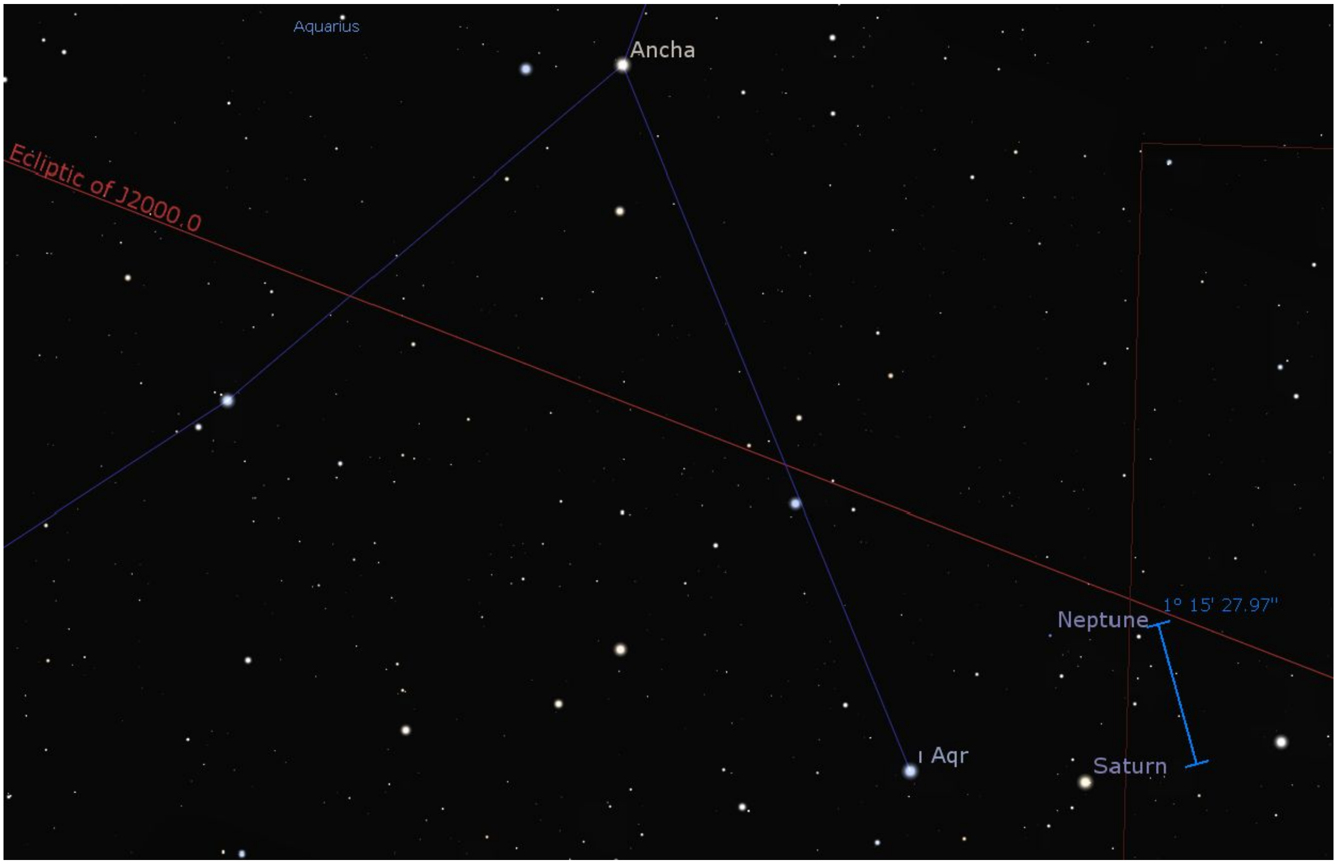
Tuesday, September 5th: Neptune Reaches Opposition



The path of Neptune through 2017.
Image credit: Starry Night Education software.

The planet Neptune reaches opposition for 2017 on September 5th at ~5:00 Universal Time (UT). Opposition for 2017 occurs in the astronomical constellation of Aquarius. In 2017, Neptune wanders along the ecliptic through Aquarius, about a degree southeast of the +3.7 magnitude star Lambda Aquarii. Slow-moving Neptune does not exit Aquarius into the adjacent constellation Pisces until 2022. Oppositions for Neptune occur roughly every 367 days, and mark the entrance of the planet into the evening sky about a month prior, and the

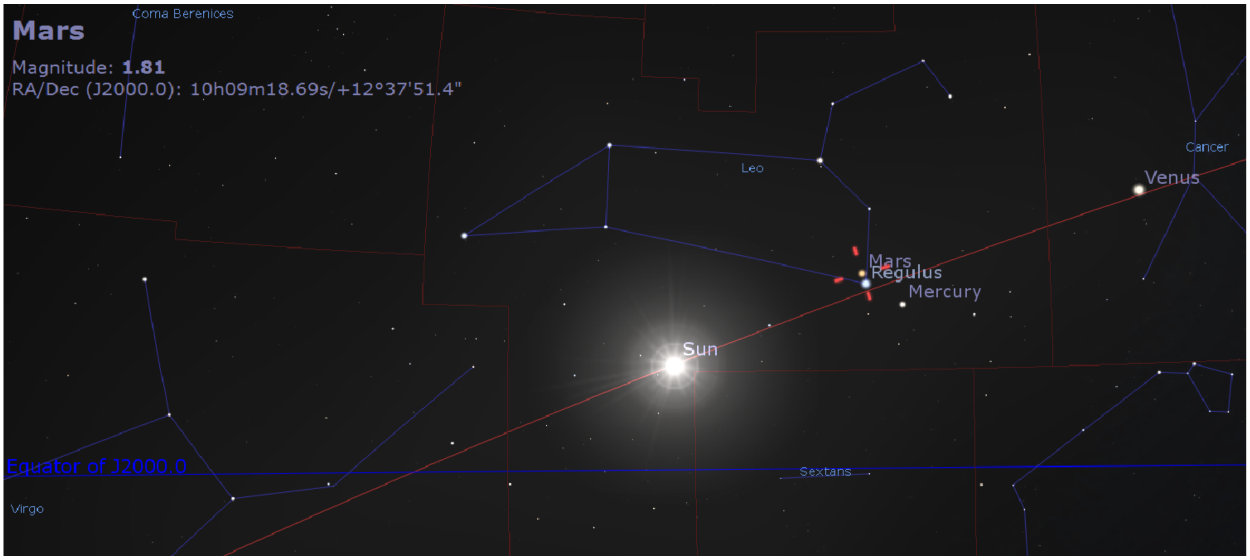
prime season for imaging and observing the planet. The last opposition for Neptune occurred on September 2nd, 2016, and the next is on September 7th, 2018. During opposition 2017, Neptune shines at magnitude +7.8 and displays a disk 6” across. Neptune is 4.3 billion kilometers or 28.94 astronomical units (AU) from the Earth during this year's opposition. With a declination of -8 degrees south, this year's opposition slightly favors the southern hemisphere. The Moon also occults Neptune 13 times in 2017, once during each lunation.



The discovery position of Neptune in Aquarius near Saturn on the evening of September 23rd, 1846. Credit: Stellarium.

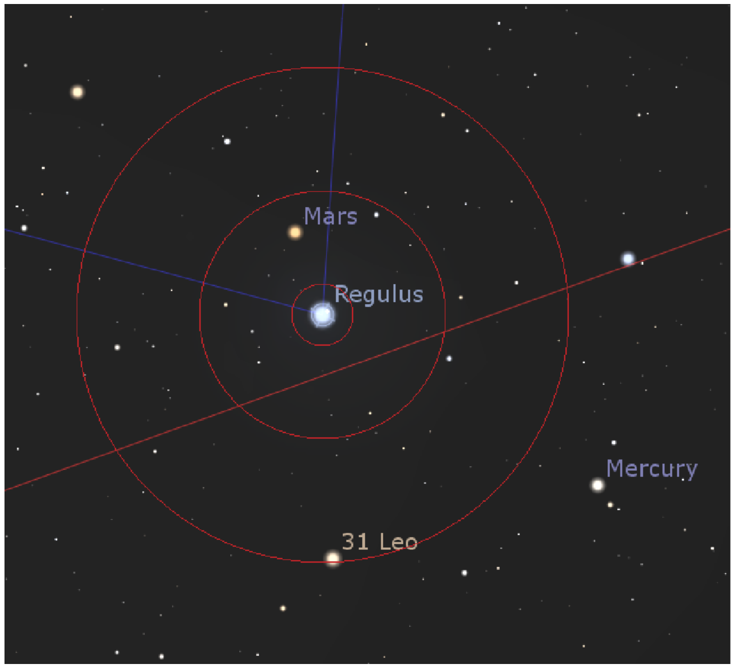
Discovered on the night of September 23rd 1846 by Johann Galle and Heinrich d'Arrest from the Berlin observatory using predictions forwarded to them by French Mathematician Urbain Le Verrier, Neptune was the first planet discovered after a systematic search. Neptune was also located in Aquarius during the time of its discovery. Orbiting the Sun once every 165 years, Neptune only just returned to its discovery position in the 2010-2011 season.

Tuesday, September 5th: A Close Conjunction of Mars and Regulus



The view on September 5th. This month sees a complex series of conjunctions and occultations involving Mars, Mercury, Venus, Regulus and the Moon in the dawn sky. Credit: Stellarium.

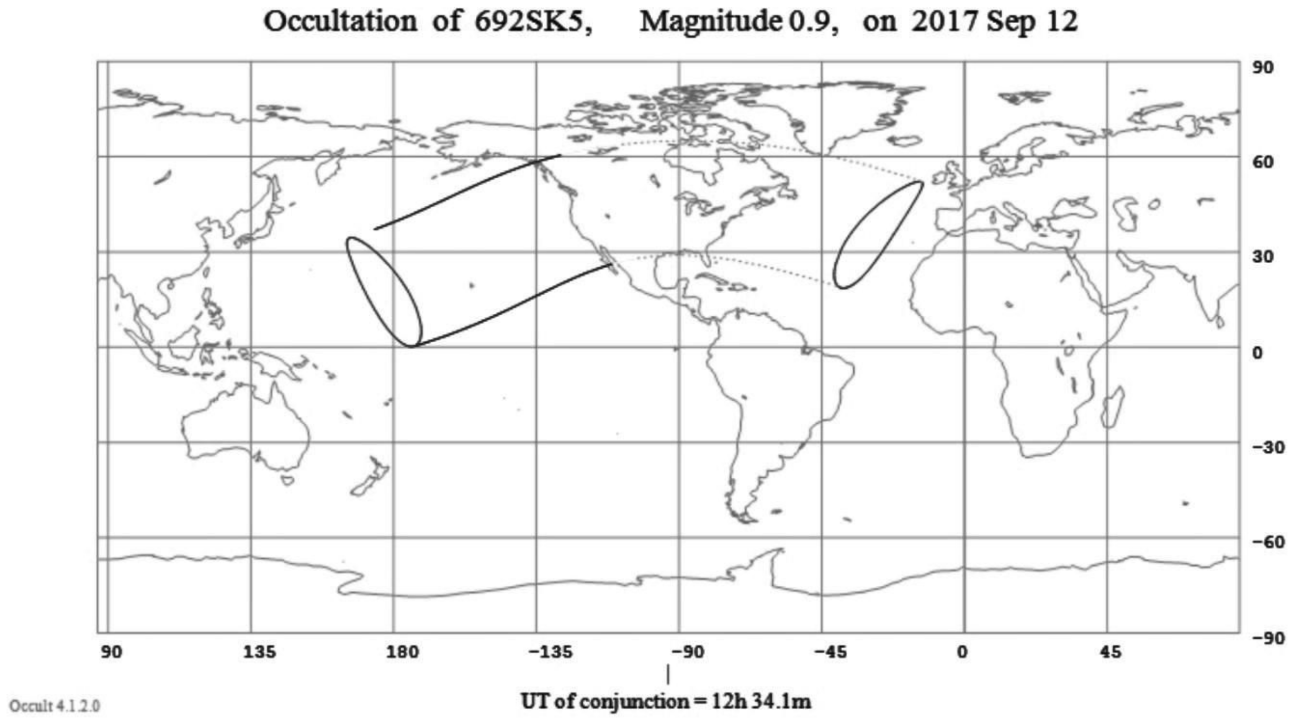
Mars and Regulus pass within 0.7 degrees (42' arc minutes) of each other in a close conjunction on September 5th. The moment of closest conjunction occurs at 12:00 Universal Time (UT). Mars shines at +1.8 magnitude and is 3.6" arc seconds in diameter, and Regulus shines at a nearly identical magnitude +1.4 at the time of closest approach. The conjunction occurs in the astronomical constellation Leo, just 13 degrees west of the Sun low in the dawn sky. Mars is 393 million kilometers or 2.6 Astronomical Units (AU) or just over 21 light minutes distant at the time of conjunction, while Regulus is 79.3 light years distant. This is the second closest planet versus bright star passage of 2017, after Venus passes 30' from Regulus just two weeks later.



The Sept 5th conjunction of Mars and Regulus with a 5 degree telrad overlay. Credit: Stellarium.

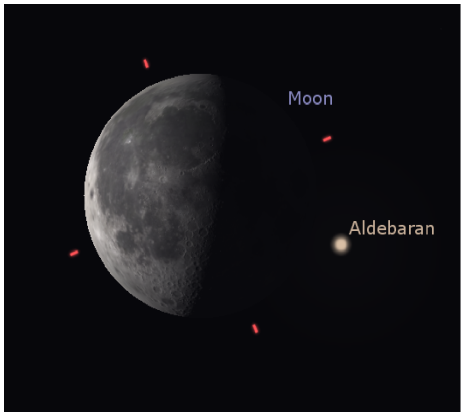
Mars passed solar conjunction on Jul 27, 2017 & is now headed towards a favorable opposition on July 27th, 2018, when it will appear 24.3” across, nearly as favorable as the opposition of 2003.

Tuesday, September 12th: The Moon occults Aldebaran



The occultation footprint of the September 12th event. Image credit Occult 4.2.

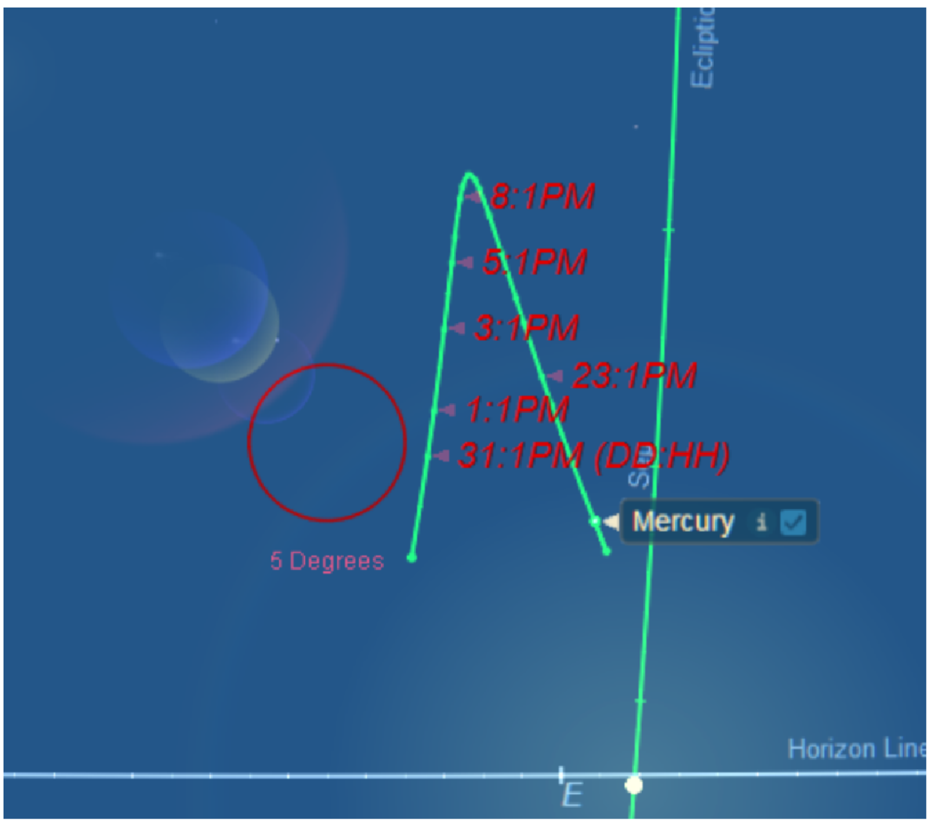
The 59% illuminated waning gibbous Moon occults the +0.9 magnitude star Aldebaran. The Moon is six days past Full during the event. Both are located 100 degrees west of the Sun at the time of the event. The central time of conjunction is 12:34 Universal Time (UT). The event occurs during the daylight hours over the contiguous United States and Canada, and under darkness for the west coast of North America, including Hawaii. The Moon will next occult Aldebaran on October 9th. This is occultation 35 in the current series of 49 running from January 29th, 2015 to September 23rd, 2018. This occultation is particularly well-placed for the U.S. West Coast during the dawn, and observers eastward may still get a good chance to see Aldebaran 'pop out' from behind the dark limb of the Moon under post-sunrise skies. There's at chance to catch a grazing occultation from southern Baja California.



The view on September 12th from the U.S. West Coast. Image credit: Stellarium

Grazing occultations are dramatic, as the background star winks through valleys and mountains along the lunar limb. Such an event can also be used to construct a profile of the limb of the Moon.

Tuesday, September 12th: Mercury Reaches Greatest Elongation



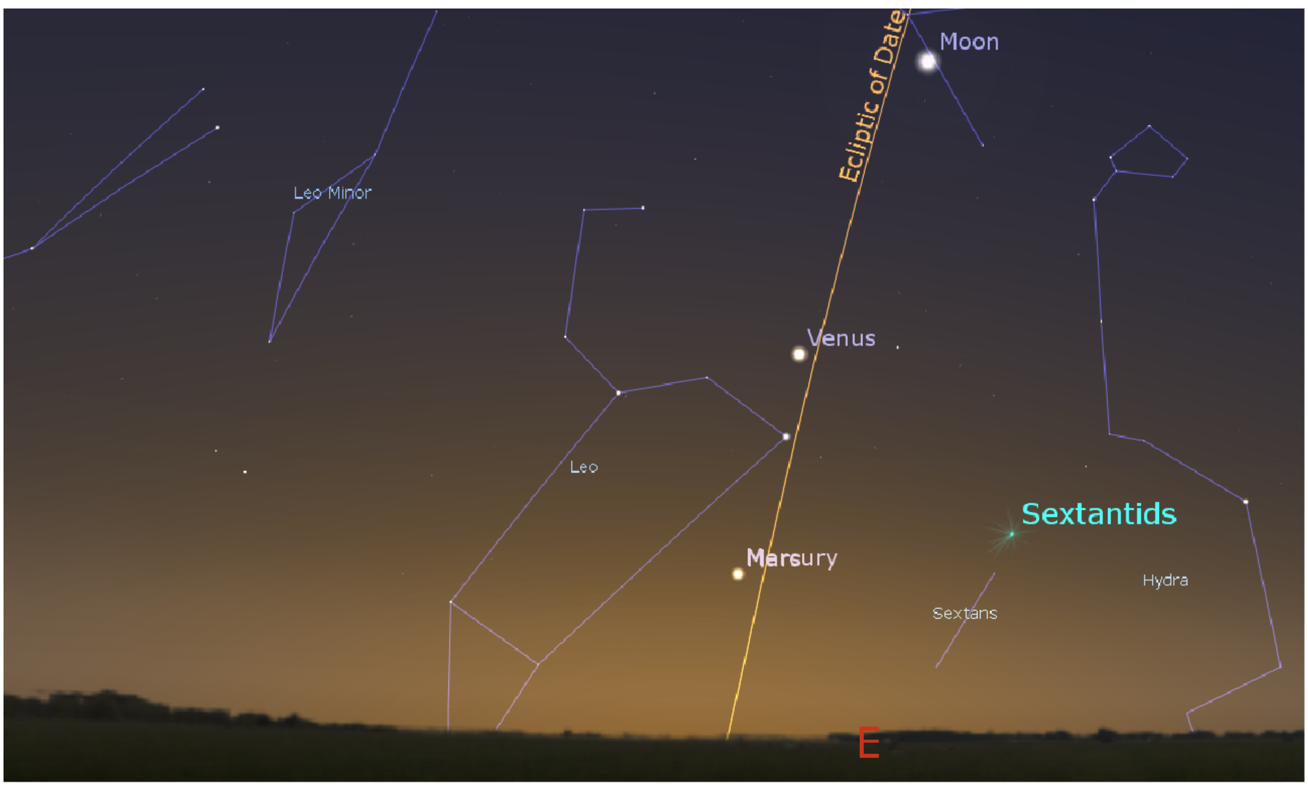
The path of Mercury from August 29th to September 28th.

Image credit: Starry Night Education Software.

The planet Mercury reaches greatest elongation 18 degrees west of the Sun in the dawn sky. The exact hour of greatest elongation occurs on September 12th at ~12:00 Universal Time (UT). Mercury is 7.2' in apparent diameter and presents a 47% illuminated disk at greatest elongation. This dawn apparition of Mercury favors viewers in the southern hemisphere. Mercury then begins to head back towards the Sun every evening until reaching superior conjunction on the far side of the Sun and the Earth on October 8th at 21:00 UT. Mercury reaches theoretical dichotomy (half phase) a day later on September 13th, and shines at a brilliancy of -0.1 magnitude on September 12th at greatest elongation. Mercury will next reach greatest eastern (dusk) elongation on November 24th. This is the final full dawn apparition for Mercury in 2017. Mercury also reaches greatest elongation just three days before reaching perihelion on September 15th.

Sighting Mercury in the twilight near greatest elongation is surprisingly easy... if you know exactly where to look for it. The oft told tale that 15th - 16th century astronomer Nicolas Copernicus never spied Mercury in his lifetime is most likely apocryphal.

Saturday, September 16th: A Close Conjunction of Mercury and Mars

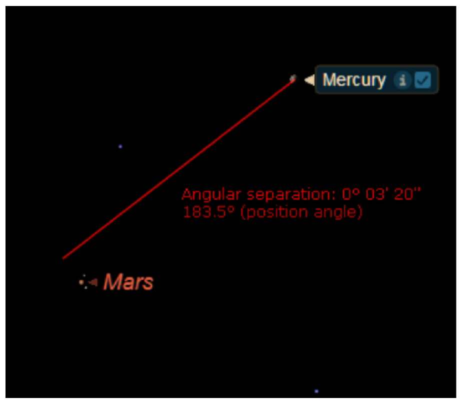


The view on the morning of September 16th looking east. Credit: Stellarium.

Mercury and Mars pass within 0.05 degrees (3' arc minutes) of each other in a close

conjunction on September 16th. Closest conjunction occurs at ~16:00 Universal Time (UT) favoring the western Pacific region. Mercury passes north of Mars during the event. Mercury shines at +0.05 magnitude and is 6.4” arc seconds in diameter, and Mars shines at +1.8 magnitude and is 3.6” arc seconds in diameter at the time of closest approach. The conjunction occurs in the astronomical constellation Leo, 17 degrees west of the Sun in the dawn sky. Mercury is 158 million kilometers or 1.058 Astronomical Units (AU) distant and Mars is 389 million kilometers or 2.6 AU distant during the conjunction. This equates to 8.8 light minutes for Mercury and 22 light minutes for Mars.

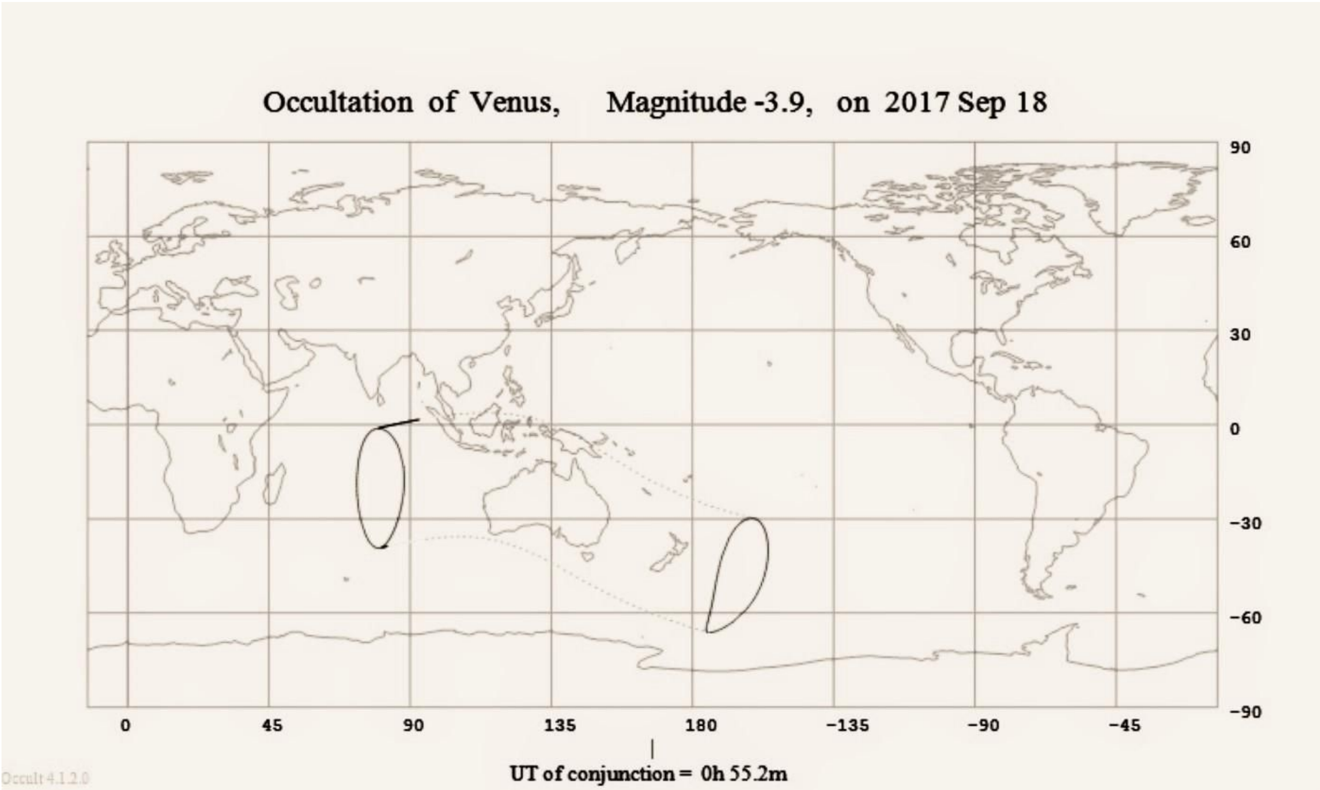
This is the **closest conjunction passage of two naked eye planets for 2017**, and the beginning of a complex series of conjunctions and occultations involving Mercury, Venus, Mars, Regulus and the Moon spanning September 16th to September 20th.



Mars & Mercury on closest approach on Sept 16th. Image credit: Starry Night Edu. Software.

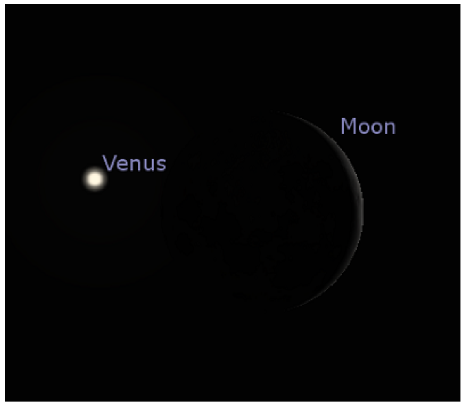
Mercury occults Mars for observers in the Middle East at dawn on the morning of Aug. 11th, 2079.

Monday, September 18th: The Moon occults Venus



The occultation footprint for the September 18th event. Image credit: Occult 4.2.

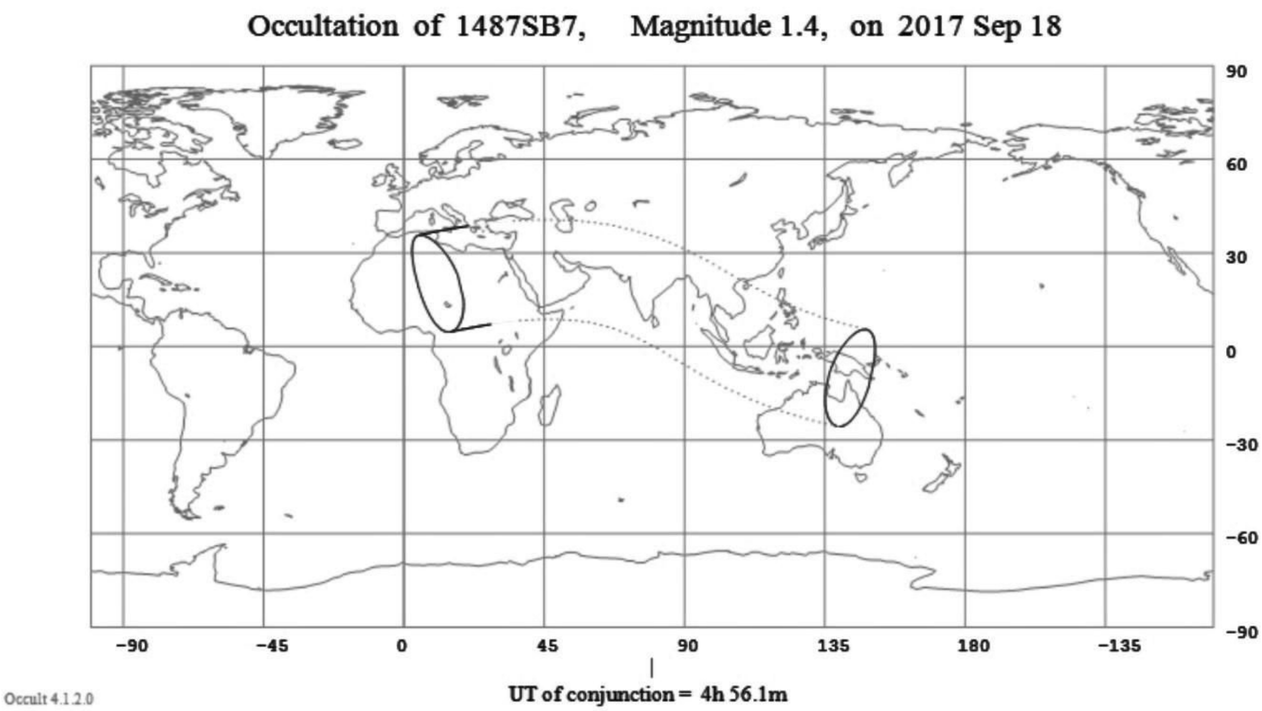
The 5.6% illuminated waning crescent Moon occults the 88% illuminated, -4th magnitude planet Venus. The Moon is 2 days from New during the event. Both are located 27 degrees west of the Sun at the time of the event. The central time of conjunction is 00:55 UT. The event occurs during the daylight hours over New Zealand and Australia, and under darkness for the central Indian Ocean, including the British territory of Diego Garcia. The Moon will next occult Venus on February 16th, 2018. Venus is located 1.4 astronomical units (AU) or 215 million kilometers distant during the occultation. This is a great time to look for Venus in the early dawn daytime sky, using the nearby crescent Moon as a guide... just be sure to block the Sun from view!



Venus near the Moon on September 18th. Image credit: Stellarium

On January 15th, 1589, startled villagers in the town of Saint-Denis, France looked up in amazement as a bright object hovered near the daytime Moon. The sighting, which has since made its way into UFO-lore, was, in fact, a daytime sighting of Venus very near the crescent Moon.

Monday, September 18th: The Moon occults Regulus



The occultation foot print for the September 18th event. Image credit Occult 4.2.

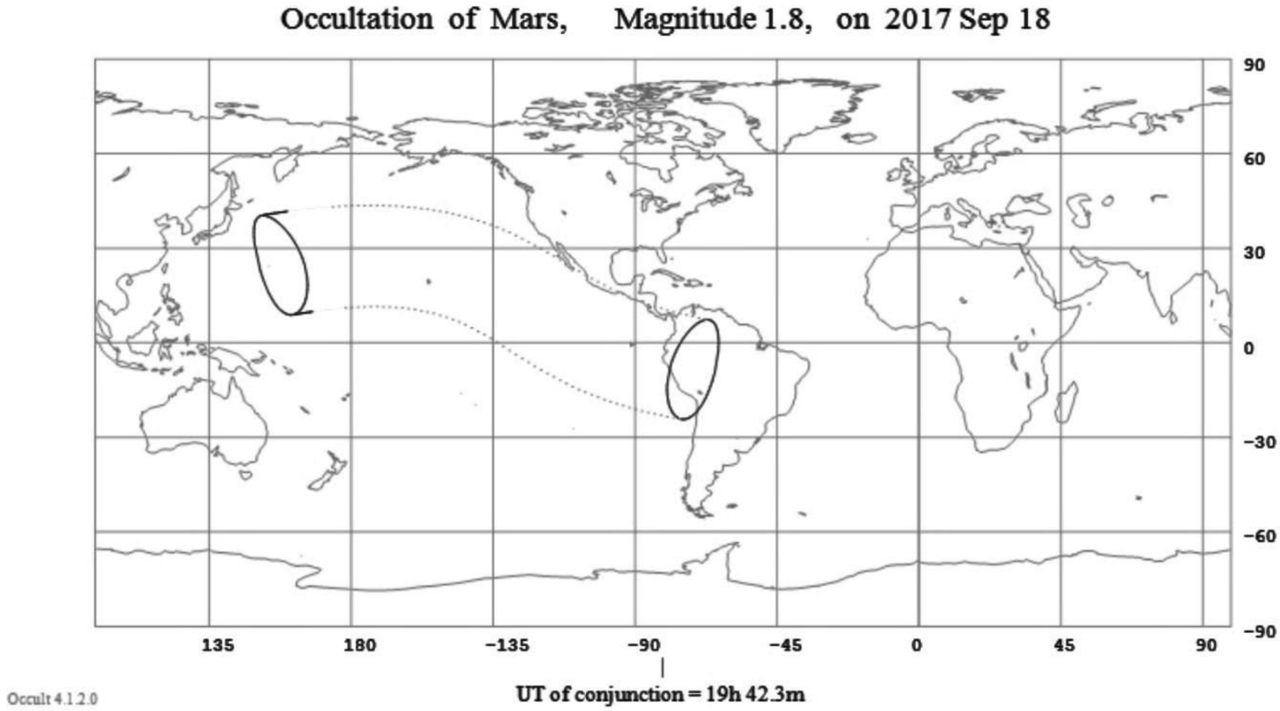
The 5% illuminated waning crescent Moon occults the +1.4 magnitude star Regulus. The Moon is 2 days from New during the event. Both are located 25 degrees west of the Sun at the time of the event. The central time of conjunction is 4:56 Universal Time (UT). The event

occurs during the daylight hours over southern Asia, and under darkness for the northern Africa, including Libya and Chad. The Moon will next occult Regulus on October 15th, 2017. This is occultation 11 in the current series of 19 running from December 18th, 2016 to April 24th, 2018. Observers in southeast Asia see the Moon occult Venus and then Regulus under daytime skies just six hours apart.

The view on September 18th from SE Asia. Image credit: Stellarium.

On March 20th, 2014 an occultation of Regulus by the asteroid 163 Erigone went unobserved across the northeastern United States due to overcast skies.

Monday, September 18: The Moon occults Mars



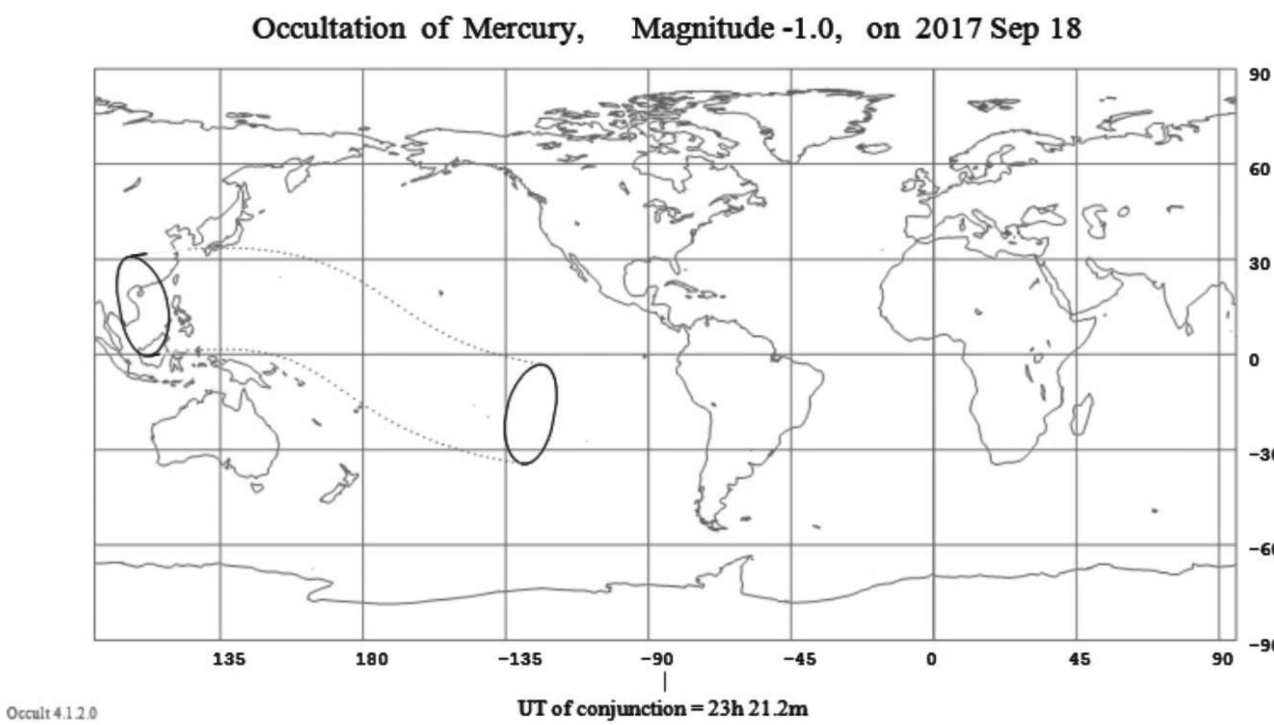
The occultation footprint for the September 18th event. Image credit: Occult 4.2.

The 2% illuminated waning crescent Moon occults the 99% illuminated, +1.8 magnitude planet Mars. The Moon is a day prior to New during the event. Both are located 18 degrees west of the Sun at the time of the event. The central time of conjunction is ~19:42 Universal Time (UT). The event occurs during the daylight hours over Hawaii, the Galapagos Islands and the western coast of Central and South America, and under darkness for the northwestern Pacific. The Moon will next occult Mars on November 16th, 2018. Mars presents a 3.6” disk and is located 2.6 astronomical units (AU) or 388 million kilometers distant during the occultation. This is the second of two occultations of Mars by the Moon for 2017, and one of five occultations of naked eye planets by the Moon for the year overall.
3 of these – one each for Venus, Mars and Mercury — occur in quick succession in mid-September.

The view on the morning of September 18th, 2018. Image credit: Stellarium.

Moving at an average speed of just over a kilometer per second, the Moon moves 30” per minute, a speed that can be discerned watching an occultation of a planet by the Moon with a telescope.

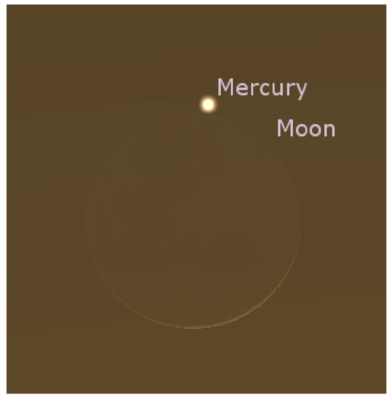
Monday, September 18th: The Moon occults Mercury



The occultation footprint for the September 18th event. Image credit: Occult 4.2.

The 2% illuminated waning crescent Moon occults the 74% illuminated, 6” diameter, -0.1 magnitude planet Mercury. The Moon is one day from New during the event. Both are located 16 degrees west of the Sun at the time of the event. The central time of conjunction is 23:21

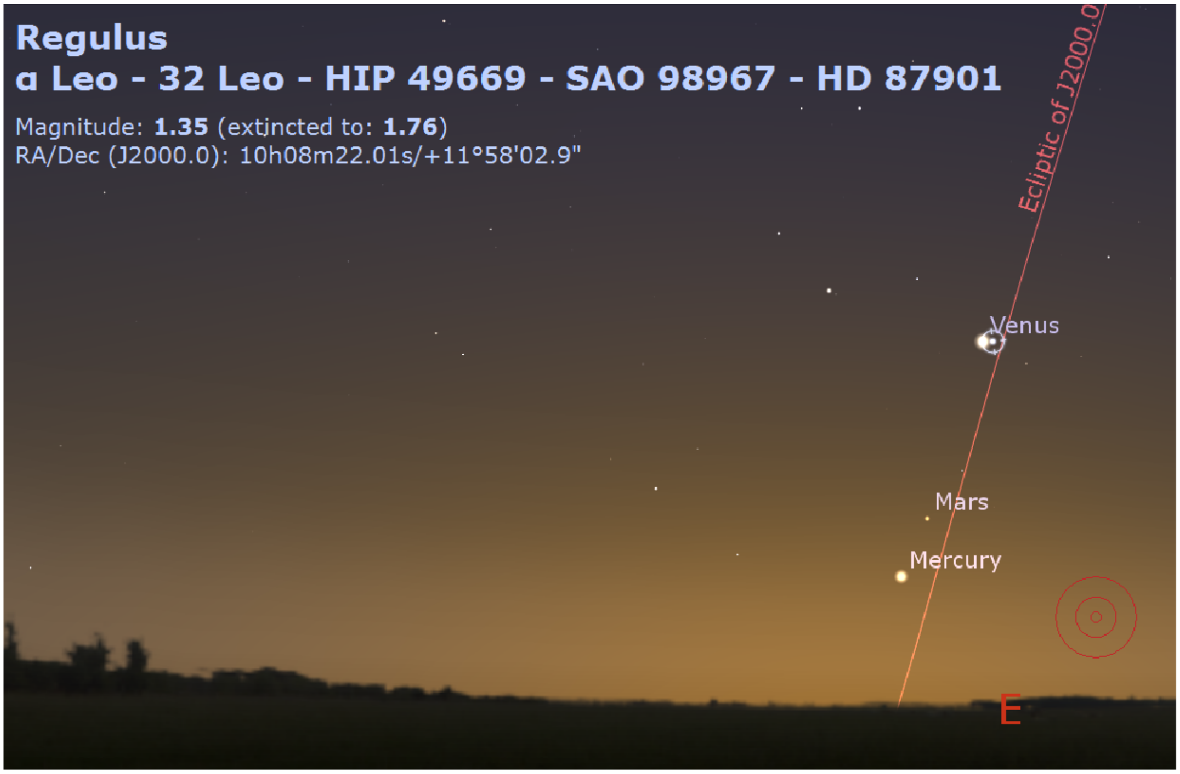
Universal Time (UT). The event occurs during the daylight hours over the central Pacific, and under twilight skies for southeast Asia, including Borneo and Vietnam. The Moon will next occult Mercury on January 27th, 2018. Mercury is located 1.1 astronomical units (AU) or 167 million kilometers distant during the occultation. This is the second and final occultation of Mercury by the Moon for 2017, and this event occurs 6 days after Mercury reaches greatest elongation.



The view from Vietnam at the time of the event. Image credit: Stellarium.

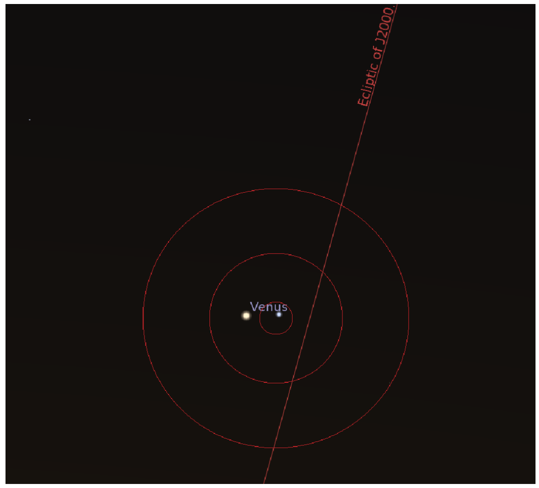
In May 1990, Stephen O'Meara sighted the razor thin crescent Moon without optical assistance, just 15 hours and 32 minutes from New.

Wednesday, September 20th: A Close Conjunction of Venus and Regulus



The view on the morning of September 20th looking east. Image credit: Stellarium.

Venus and Regulus pass within 0.5 degrees (30' arc minutes) of each other in a close conjunction on September 20th, 2017. Closest conjunction occurs at ~2:00 Universal Time (UT) favoring western Asia and eastern Africa. Venus shines at -3.9 magnitude and is 12" arc seconds in diameter, and Regulus shines at +1.4 magnitude at the time of closest approach. The conjunction occurs 27 degrees west of the Sun in the dawn sky. Venus is 216 million kilometers or 1.4 Astronomical Units (A.U.) or 11.6 light minutes distant, and Regulus is 79 light years distant during the conjunction. Venus moves about a degree (twice the apparent diameter of a Full Moon) per day past Regulus during the event. This is the **closest pass of a planet near a bright star for 2017.**



The conjunction, including a five degree Telrad overlay. Credit: Stellarium.

Venus occults three stars in the coming millennium: Regulus (October 1st, 2044), Spica (September 2nd, 2197), and Antares (November 17th, 2400).

Friday, September 22nd: The September Equinox

(am image)

The southward equinox occurs at 14:21 Universal Time (UT), marking the beginning of astronomical Fall for the northern hemisphere, and the start of Spring for the southern. This is an exact moment when the Sun's declination equals 0 as seen from the Earth. The two points where the ecliptic or the imaginary path the Sun seem to trace out along the celestial sphere meets the celestial equator are known as the *equinoctial points*.

In the 21st century, the September Equinox last fell on September 22nd on 2016, and will fall on the 22nd or the 23rd until 2092, when it will begin falling on September 21st every fourth year.

The Equinox (literally meaning 'equal nights' in Latin) means that night and day are nearly equal worldwide, and that the Sun rises due east of an observer on the equinox and sets due west.

The Full Moon nearest to the September Equinox is known as the Harvest Moon, a time when farmers use the extra illumination at dusk to bring in crops. In 2017, the Harvest Moon actually falls on October 5th.

The term *equilux* is sometimes used to discern the difference between the true equinox and the point when sunlight length actually equals the length of the night. Several factors play a role in this, including the time it takes the physical diameter of the Sun to clear the horizon, atmospheric refraction, and the observer's true position in their respective time zone. The equilux occurs within a few days of either equinox.

Saturday, September 23rd: The Middle of GEO Satellite Eclipse Season

The second and final geostationary satellite flare and eclipse season of the year occurs. This is a three week span centered on either equinox for a given year. Orbiting the Earth at a distance of 35,785 kilometers distant, these satellites are only normally visible in a large telescope at around +12th magnitude. Just prior to entering the Earth's shadow, however, a geostationary satellite can on occasion flare up briefly to naked eye visibility. The Earth's shadow is larger at geostationary distance than it is during lunar eclipse, and eclipses of geosats can last up to 68 minutes in duration. GeoSat flares frequently turn up on long exposure shots of the night sky.

What you're seeing during a satellite flare event is the specular reflection of the Sun off of the satellite's solar panels. Most of the satellites visible to the unaided eye are in low Earth orbit, a few hundred kilometers above the Earth and whizzing along once around the Earth every 90 minutes.

In addition to the famous Iridium constellation of communications satellites in low Earth orbit, several other classes of satellites can flare on occasion, including the Hubble Space Telescope, International Space Station, and the SkyMed series of satellites.

Geostationary communications satellites are in a fixed orbit over the Earth's equator and are, as the name suggests, set in a stationary orbit going once around the Earth every 23 hours and 56 minutes. A geosynchronous orbit, however, can be inclined with respect to the equator, and will seem to bob up and down against the background field of stars. Deep sky images of the M42 nebula in Orion are notorious for such 'photo-bombs' from geosynchronous satellites. All geostationary satellites are geosynchronous, but not all geosynchronous satellites are geostationary.

Another type of semi-stationary orbit – a Molniya orbit – was pioneered by the Soviet Union. It places a satellite in an elliptical 12 hour orbit that returns it back to the same location over the Earth once every 24 hours.

September Challenge: Looking for Lunar Letters

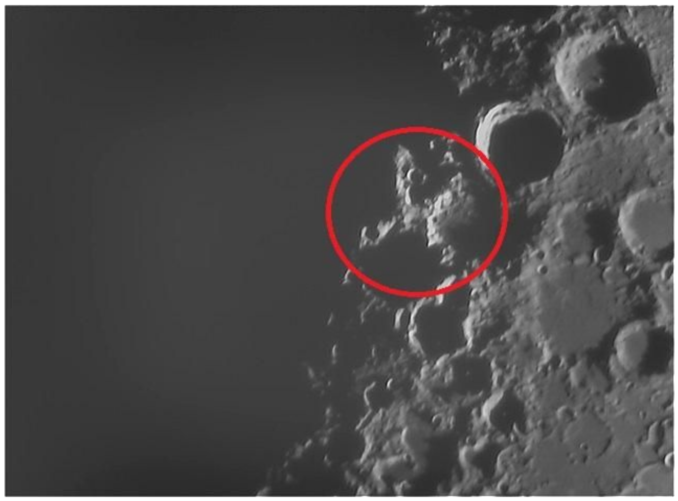
There's an alphabet soup of strange features awaiting observers on the Moon.

Ready for some astro-pareidolia? Look no further than Earth's solitary natural satellite.

Every culture sees something different in the face of the Moon. The Chinese saw a rabbit, and named the diminutive Yutu 'Jade Rabbit' rover in honor of the myth. In Longfellow's *The Song of Hiawatha*, the face of the Moon is the body of the Iroquois Indian chief's grandmother

flung up against the Moon. The Greeks believed the Moon was a large polished mirror, reflecting back a view of the Earth below. Of course, if this were indeed the case, it would be hard to explain just how the image doesn't shift in the night, as the Moon moves across the sky.

A cosmic Rorschach Test, the Moon is tidally locked in the Earth's embrace, keeping its far side forever hidden from our terrestrial vantage point. The subtle rocking motions known as *libration* and *nutation* allow us to peer over the edges of the lunar limb just a bit, letting us to see 59% of the Moon's total surface. A true glimpse of the far side had to wait until the Soviet Luna 3 spacecraft flew past the Moon on October 7th, 1959 and returned the first blurry images.



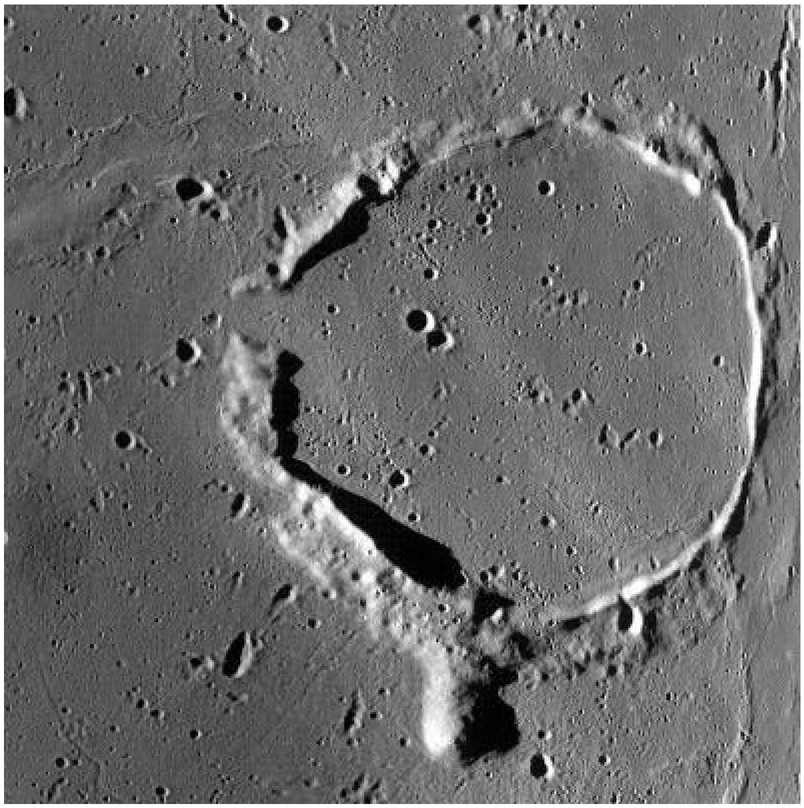
Introducing... the Lunar X. Photo by author.

One of the most famous of the lunar letters is the Lunar X, also referred to as the Werner X or Purbach Cross. This is the confluence of the rims the the craters La Caille, Blanchinus and Purbach located in the lunar highlands. The Lunar X becomes visible as the waxing gibbous Moon reaches seven days illumination, about 6 to 10 hours (depending on the incident sun angle) after First Quarter phase and 6 to 10 hours before Last Quarter. The Lunar X can stand out in dramatic contrast against the darkness just beyond the lunar terminator, if you can manage to catch it just as the first rays of sunlight strike the top of the ridge. Remember, the span from sunrise to sunset lasts two weeks on the Moon, and looking Earthward, you'd see the Earth in an opposite phase.

Sometimes, the Curtiss Cross feature is also referred to as a lesser known Lunar X. The confluence of two or more crater rims on the battered surface of the Moon is far from uncommon.

Sweeping northward, the Lunar V feature in the Mare Vaporum is also sometimes prominent around the same time as the Lunar X, and it's possible on occasion to nab both in the same image.

Other lunar letters of note include the Lunar S in Sinus Asperitatis (visible at 47% illumination just before First Quarter), the Lunar W located near Mons Rümker on the lunar limb in the Oceanus Procellarum, and our favorite of the lesser known lunar letters, the Lunar Q of crater Kies in the Mare Nubium reaching favorable illumination 10 days after New.



A 'Lunar Q'. Image credit: NASA/LRO.

Of course, circular craters provide a wealth of candidates for the 'Lunar O,' and straight line features such as the Rupes Recta lunar straight wall feature in the Mare Nubium could pass for the 'Lunar I'. Hey, who wouldn't love to spell out their name in craters? Maybe some of the recently mapped worlds such as Mercury, Pluto or Ceres could come to the rescue, filling in the final letters?

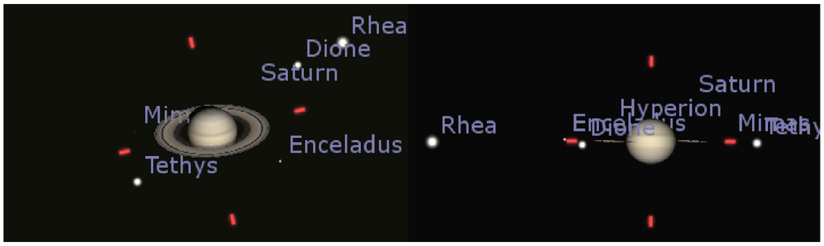
Many of these are optical illusions, tricks of lighting as the angle of the rising Sun slowly changes, casting shadows across the lunar landscape. Two illumination effects at work here straight out of art class are what's known as the *Clair-obscur* or chiaroscuro phenomenon of light and shadow, and the Trompe l'Oeil effect, a three-dimension illusion of forced perspective. Follow features such as the Lunar X night to night as the Moon heads towards Full, and you'll notice they nearly vanish amid the glare as the Sun shines down from high overhead. The vanishing 'face on Mars' seen in the early Viking 1 orbiter images was the result of the same trick of light. The 'face' vanished once the Mars Global Surveyor re-imaged the region during a pass at near-full illumination in 2001. Hey, why don't conspiracy theorists

ever cite the 'Man in the Moon' as an artificial construct?

Why lunar letters? Well, I think its neat to see something as familiar yet improbable as a gleaming letter on the lunar surface staring back at you at the eyepiece. If you look long and hard enough, the Universe will produce just about anything, including telescope building primates with a language and an alphabet written in the heavens.

October 2017

Sunday, October 1st: Saturn's Rings at Their Widest



Saturn in 2017 (left) versus 2009 (right). Image credit: Stellarium.

In 2017, Saturn's rings appear at their widest as seen from the Earth. This occurs once every 29 years, as Saturn orbits around the Sun and its rings appear edge-on, to wide, and then edge-on again. At their widest, the rings are tipped 27 degrees open relative to our Earthly vantage point. The last time the rings were open this wide was 2003, and they won't appear this wide again until 2032.

This year, the northern hemisphere of Saturn is tipped Earthward. After 2017, the rings will go back towards edge-on again in 2025, as last occurred in 2009. Saturn's rings substend about 43” across, versus the ochre disk of the planet itself, which spans 18” near opposition. The planet last reached opposition earlier this year on June 15th and will do so again on June 27th, 2018.

On October 1st, the rings span 38” across and the planet shines at magnitude +0.5 in the astronomical constellation of Ophiuchus, about 74 degrees east of the Sun in the dusk sky.

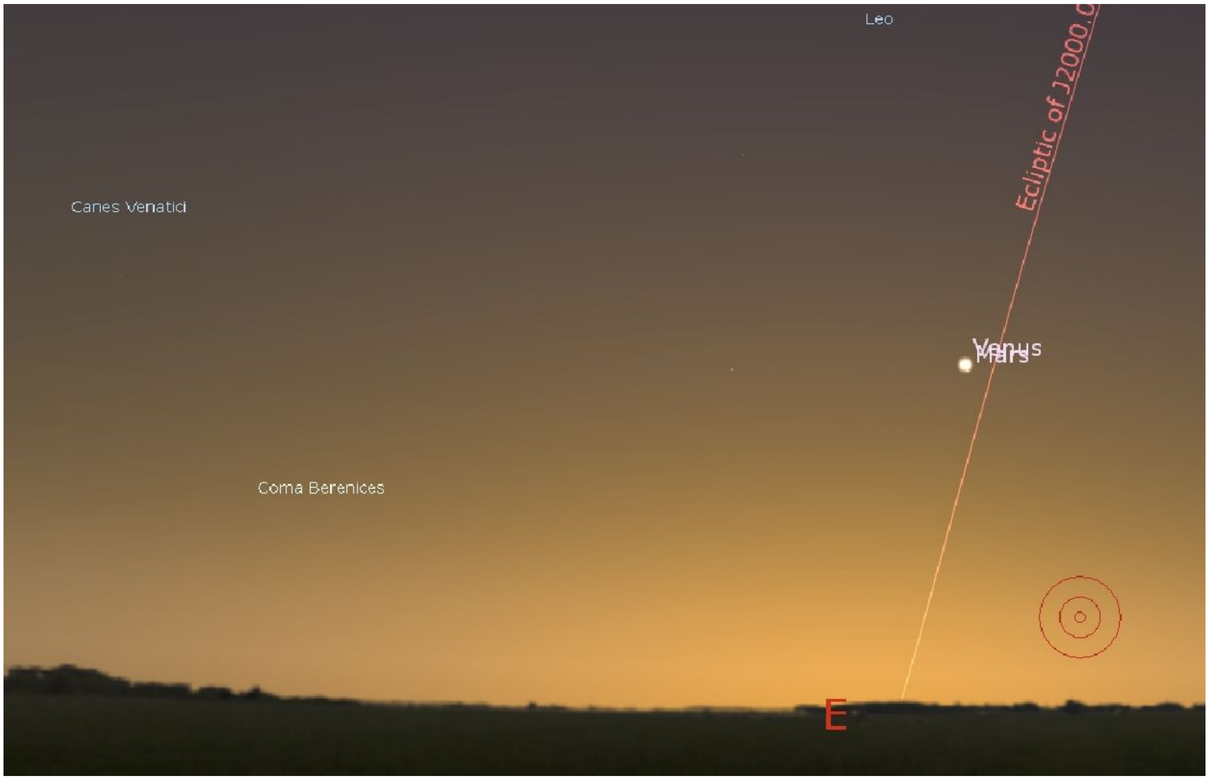
At opposition, the rings add about half a magnitude in brightness at their widest. In addition to the 29 year long cycle, the orbit of the Earth adds an apparent one year 'wobble' to the rings as well.

Physically, the rings are 280 thousand kilometers across from tip to tip, spanning 73,000 kilometers wide and about 10 meters to 1 kilometer in thickness.

The changing tilt of Saturn's rings: from 2011-2016. Image credit and copyright: Andrew Symes.

One of the most splendid sights through even a small telescope, Galileo first spied the rings of Saturn in 1610. Perplexed, he sketched what he saw through his crude telescope as more of a world with double lobes. In 1655, Christiaan Huygens was the first astronomer to correctly deduce that Saturn's rings were actually physically separated from the globe of the planet.

Thursday, October 5th: A Close Conjunction of Venus and Mars

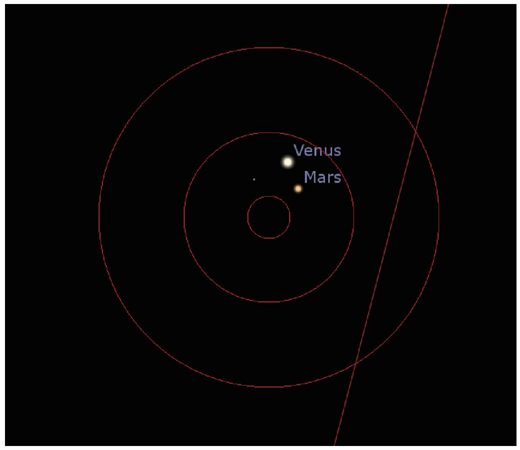


Looking east at dawn on the morning of October 5th. Credit: Stellarium.

Venus passes within 0.2 degrees (12' arc minutes) north of Mars in a close conjunction on October 5th. Closest conjunction occurs at ~16:00 Universal Time (UT) favoring the western Pacific. Venus shines at -3.9 magnitude and is an 11” arc seconds in diameter, 92% illuminated disk, while Mars shines at +1.8 magnitude and is 3.7” arc seconds in diameter at the time of closest approach.

The conjunction occurs in the astronomical constellation Leo, 24 degrees west of the Sun in the dawn sky. Venus is 226 million kilometers or 1.5 Astronomical Units (AU), and Mars is 379.5 million kilometers or 2.5 AU distant during the conjunction. This equates to 12 light minutes for Venus and 20.8 light minutes for Mars.

This is the second closest planet-planet conjunction of 2017, and is better placed for observation than last month's Mars-Mercury conjuction on September 16th.



Mars & Venus on closest approach, 5 degree telrad FoV included. Credit: Stellarium.

Shining over five full magnitudes fainter than Venus, Mars is only 1/100th as bright as its partner during this conjunction. Standing on Mars, the Earth-Moon pair would look similar in the twilight sky.

Monday, October 9th: The Moon occults Aldebaran

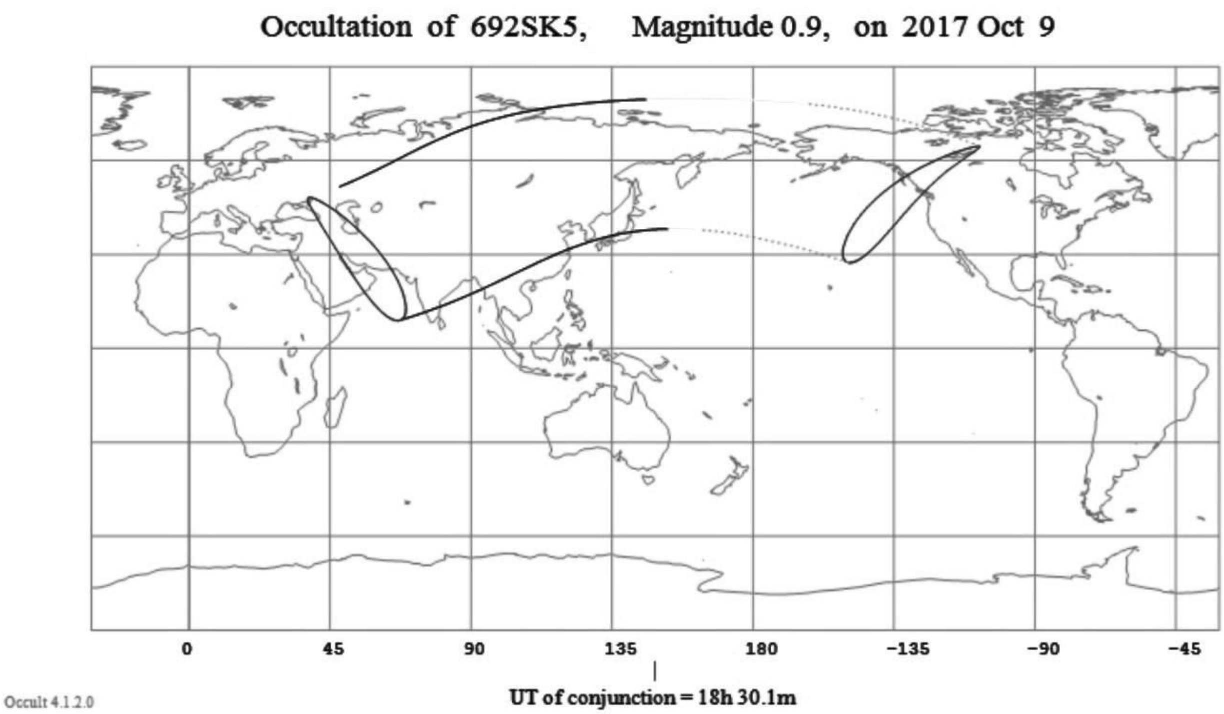


Image credit Occult 4.2

The 80% illuminated waning gibbous Moon occults the +0.9 magnitude star Aldebaran. The Moon is 4 days past Full during the event. Both are located 127 degrees west of the Sun at the time of the event. The central time of conjunction is 18:30 Universal Time (UT). The event

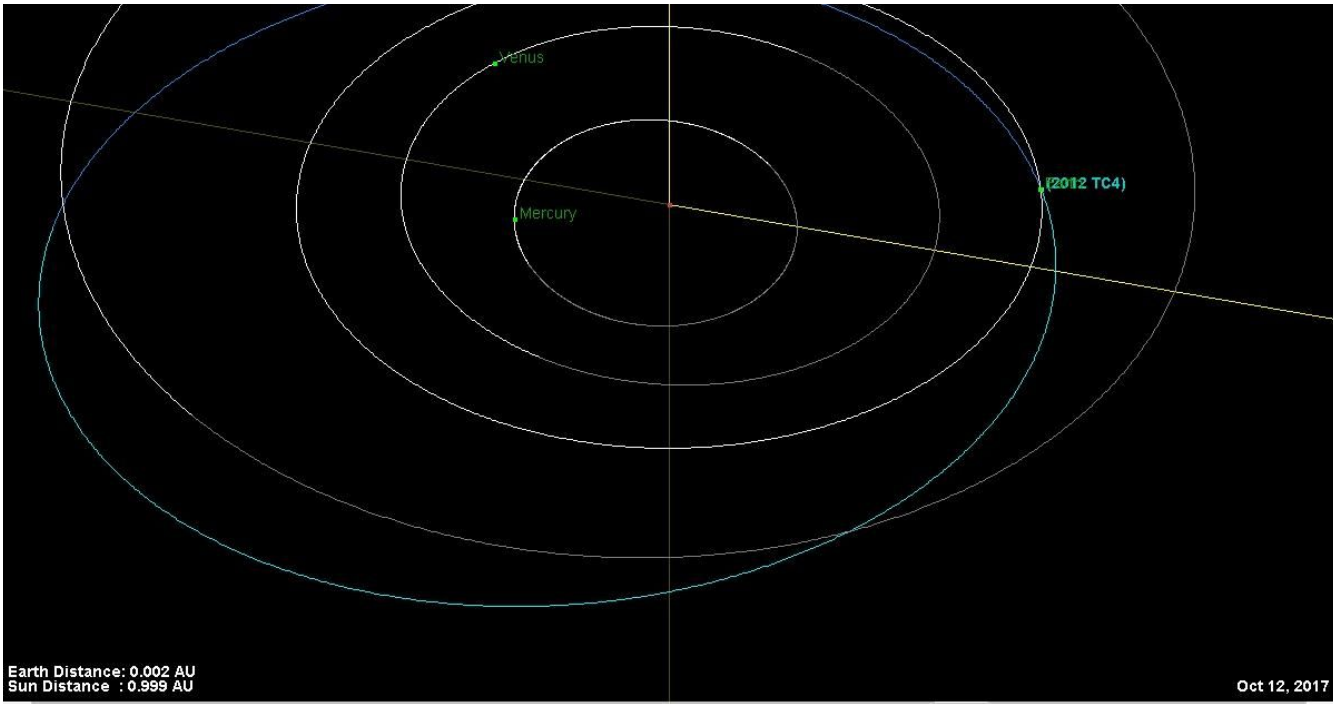
occurs during the daylight hours over Alaska and northeastern Asia, and under darkness for central Asia, including India, China and the Koreas. The Moon will next occult Aldebaran on November 6th. This is occultation 36 in the current series of 49 running from January 29th, 2015 to September 23rd, 2018. This occultation is especially well placed for the large swath of humanity living in the populous central Asian regions.

The view on October 9th from central Asia. Image credit: Stellarium.

A phenomenon known as the *Coleridge Effect* describes the optical illusion of a star seeming to 'hang' between the limb of the Moon during an occultation. This takes its name from a line in Samuel Coleridge's *Rime of the Ancient Mariner:*

While clome above the Eastern bar
The horned Moon, with one bright star
Almost atween the tips.

Thursday, October 12th: Asteroid 2012 TC4 passes near Earth



The orbit of asteroid 2012 TC4 through the inner solar system. Image credit: NASA/JPL.

Earth-crossing asteroid 2012 TC4 passes 0.03 times the Earth-Moon distance (~7,200 miles or 11,520 kilometers, nominal pass) on October 12th. Orbiting the Sun once every 1.7 years, 2012 TC4 was discovered by the PanSTARRS sky survey on October 14th, 2012. This 20-meter asteroid made a close (0.247 times lunar distance, or ~95,000 kilometers) pass near the Earth on October 12th, 2012. With an absolute magnitude of +26.7, expect the asteroid to shine at +15th magnitude on closest approach, bright enough to be visible using a large telescope.

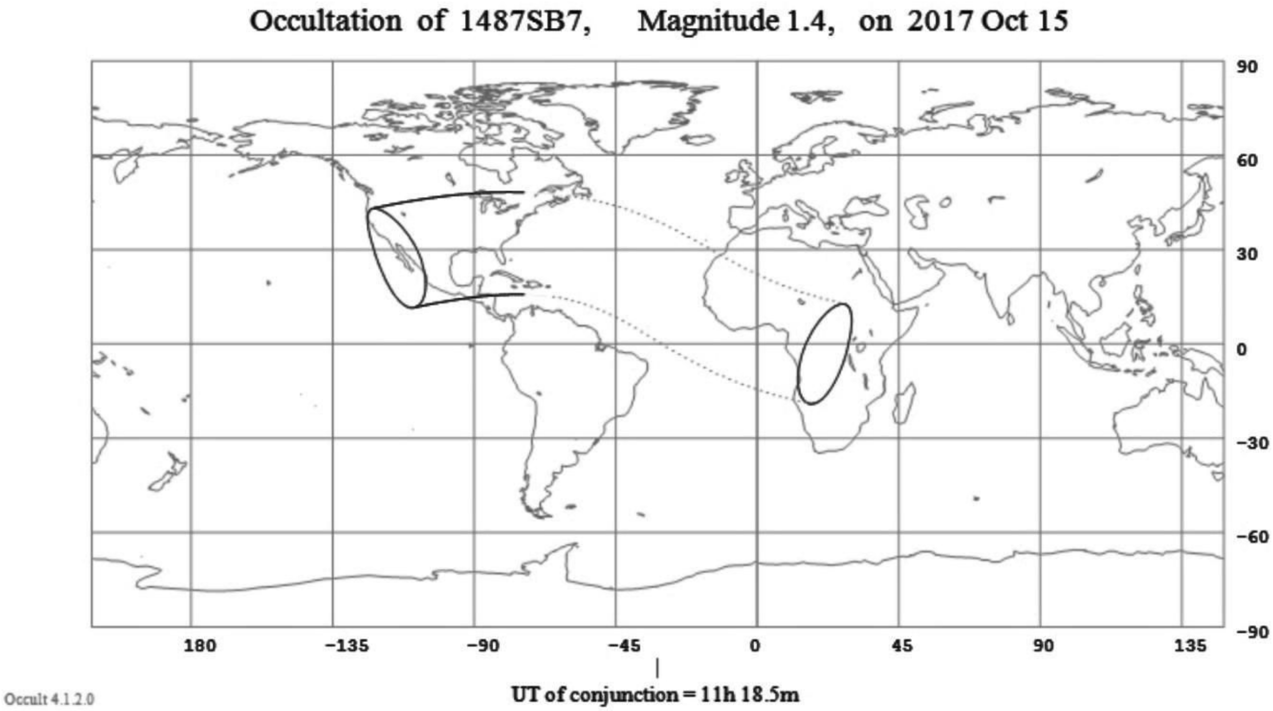
This pass is only 1/3rd the distance to geosynchronous orbit. The pass favors South America, the southern Pacific and Australia under dark skies at around 3:29 Universal Time (UT).

Keep in mind, this asteroid has only been observed over an observational arc of seven days, so its impossible to make a good finder usable chart this far out. Watch the pages of *Universe Today* online in the weeks leading up to the pass for full coverage of the event.

This is the closest pass of 2012 TC4 near the Earth for this century, and the next pass is set for September 25th, 2038 at 30,000 miles distant.

On April Friday the 13th, 2029, asteroid 99942 Apophis will pass 19,400 miles from the Earth.

Sunday, October 15th: The Moon occults Regulus



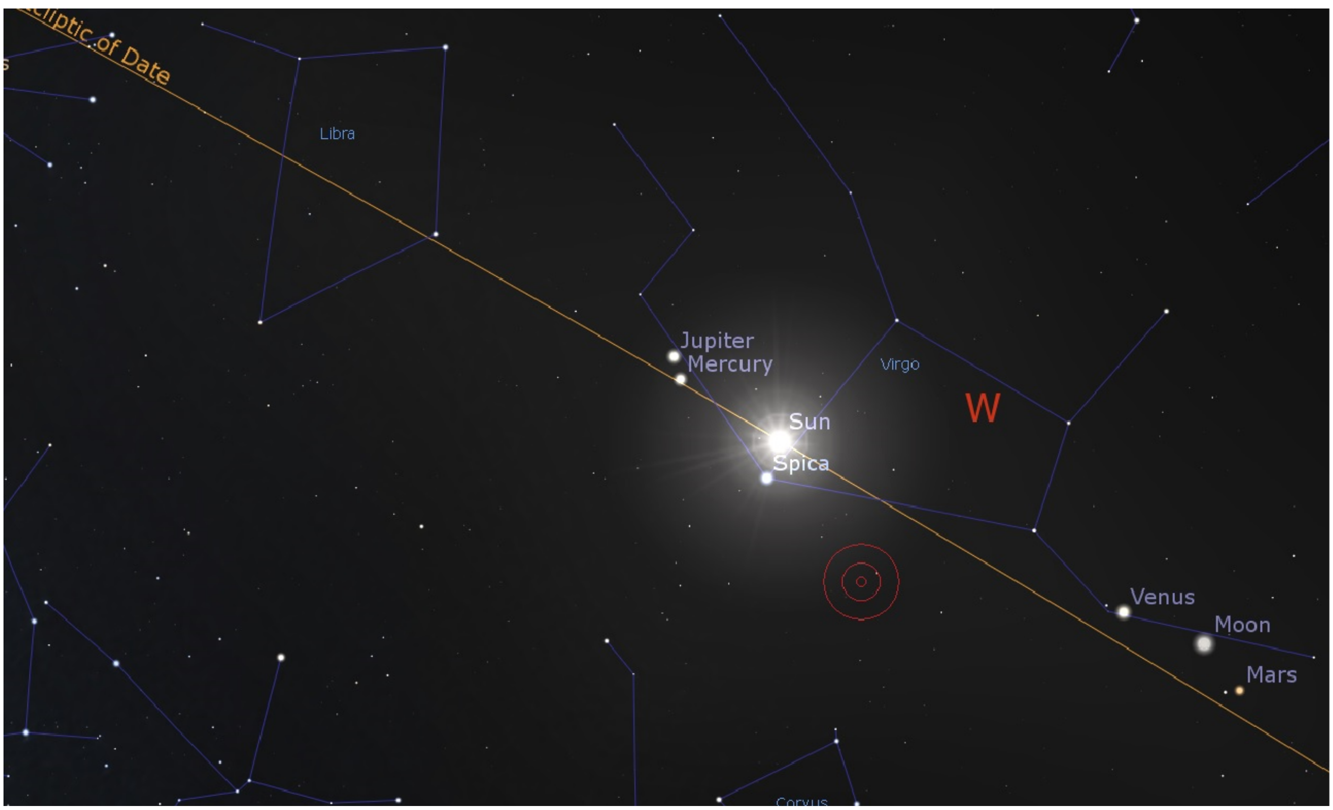
The Occultation footprint for the October 15th event. Image credit Occult 4.2.

The 20% illuminated waning crescent Moon occults the +1.4 magnitude star Regulus. The Moon is four days from New during the event. Both are located 53 degrees west of the Sun at the time of the event. The central time of conjunction is 11:19 Universal Time (UT). The event occurs during daylight hours over central Africa, and under darkness for southern North America, including Mexico, Cuba and the SE United States. The Moon will next occult Regulus on November 12th, 2017. This is occultation 12 in the current series of 19 running from December 18th, 2016 to April 24th, 2018. This is the best pre-dawn occultation of Regulus for the United States in 2017.

The view on October 15th. Image credit: Stellarium.

The Moon occults Regulus 220 times in the 21st century from 2001 to 2100 AD, the least of any +1st magnitude star.

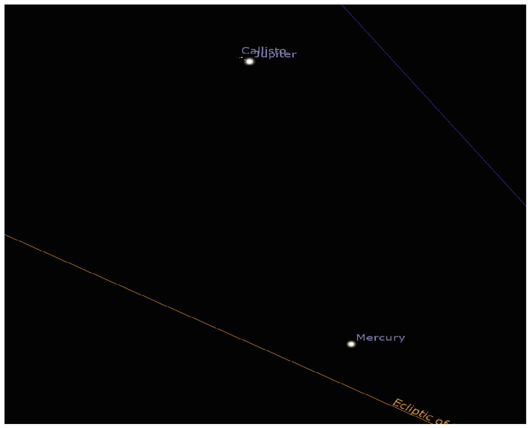
Wednesday, October 18th: A Close Conjunction of Mercury and Jupiter



The wide view of the planetary line-up on October 18th. Credit: Stellarium.

Mercury and Jupiter pass within 0.9 degrees (54' arc minutes) of each other in a close conjunction on October 18th. Closest conjunction occurs at ~9:00 Universal Time (UT).

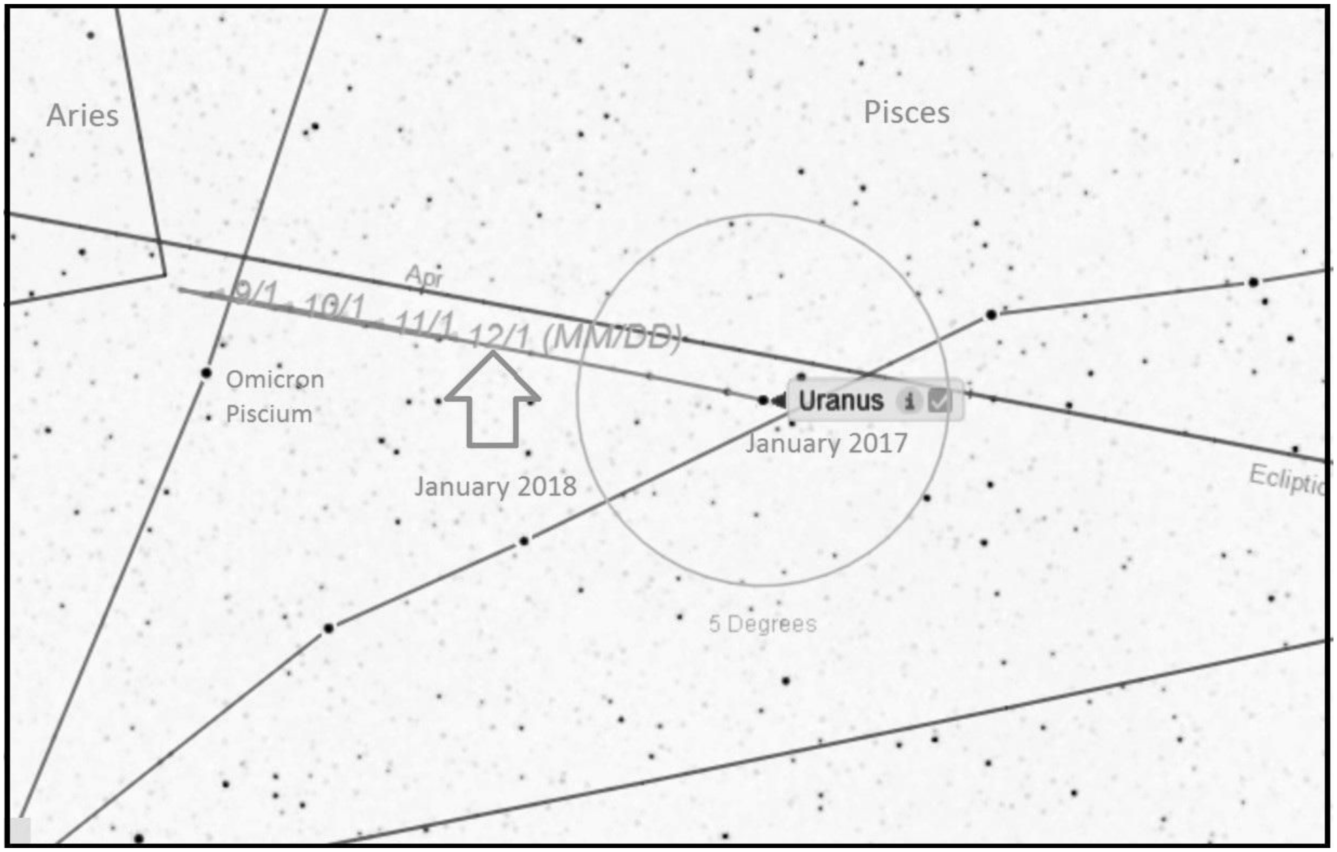
Mercury shines at -0.05 magnitude and is 4.7” arc seconds in diameter, and Jupiter shines at -1.7 magnitude and is 31” arc seconds in diameter at the time of closest approach. The conjunction occurs in the astronomical constellation Virgo, 7 degrees east of the Sun in the dusk sky. Mercury is 213 million kilometers or 1.4 Astronomical Units (AU), and Jupiter is 962 million kilometers or 6.4 AU distant during the conjunction. This equates to 11.6 light minutes for Mercury and 53 light minutes for Jupiter. This is a difficult observation, owing to the proximity of the Sun. Mercury, the smallest planet in the solar system, is 1/6,358th as massive as Jupiter, the largest planet in our solar system.



Jupiter versus Mercury: a narrow field of view. Image credit: Stellarium.

Ganymede, Jupiter's largest moon, is 4% larger than Mercury in diameter.

Thursday, October 19th: Uranus Reaches Opposition



The path of Uranus through the astronomical constellation Pisces in 2017. Image credit: Starry Night Education software.

The planet Uranus reaches opposition for 2017 on October 19th at ~17:00 Universal Time (UT). Opposition for 2017 occurs in the constellation Pisces. In 2017, Uranus wanders along the ecliptic in Pisces near the Aries border, near the +4th magnitude star Omicron Piscium. Oppositions for Uranus occur on average every 370 days, and mark the entrance of the planet into the evening sky about a month prior, and the prime season for imaging and observing the planet. The last opposition for Uranus occurred on October 15th, and the next is October 24th, 2018. During opposition 2017, Uranus shines at magnitude +5.8 and displays a disk 3.6” across. Uranus is 2.9 billion kilometers or 19.7 astronomical units (AU) from the Earth during this year's opposition. With a declination of +10 degrees north of the celestial equator, this year's opposition slightly favors the northern hemisphere. Uranus has five large moons that are within range of large backyard telescopes during opposition. (see our *Solar System Moon Challenge*).

Famously tipped over on its side, the orbits of moons of Uranus were edge on as seen from

the Earth in 2007, and will present a similar view in 2049. In 2029, we will stare directly down at the rotational pole of Uranus.

Saturday, October 21st: The Orionid Meteor Shower

The location of the Orionid meteor shower radiant and 2AM local. Credit: Stellarium.

The Orionid meteors are expected to peak on October 21st worldwide. The shower is active for a one month period from October 2nd to November 2nd, and can vary with a Zenithal Hourly Rate (ZHR) of 10-70 meteors per hour. In 2017, the Orionids are expected to produce a maximum ideal ZHR of 20 meteors per hour. The radiant of the Orionids is located at Right Ascension 6 hours 24 minutes, declination 15 degrees north at the time of the peak in the constellation of Orion.

The Moon is a slim 2% illuminated waxing crescent at the peak of the Orionids, making **2017 a favorable** for this shower. In previous years, the Orionids produced a ZHR=20 (2014) and a ZHR of 30 (2013).

The Orionid meteors strike the Earth at a moderate to fast velocity of 66 km/s, and produce a high ratio of fireballs with an *r* = 2.5. The source of the Orionids is none other than periodic comet 1/P Halley.   Unlike most meteor showers, the Orionids display a very unpredictable

maximum – many sources decline to put a precise date on the shower's expected maximum at all.

On some years, the Orionids barely top 10 per hour at their maximum, while on others they display a broad peak. One 1982 study by a Czech group suggested a twin peak for this shower, looking at activity from 1944 to 1950. Halley last paid the inner solar system a visit in February 1986, and will once again reach perihelion on July 28th, 2061.

October's Challenge: The Nearest Stars, Past and Present

A Brief Guide to the Brightest Stars in the Sky Past, Present and Future.

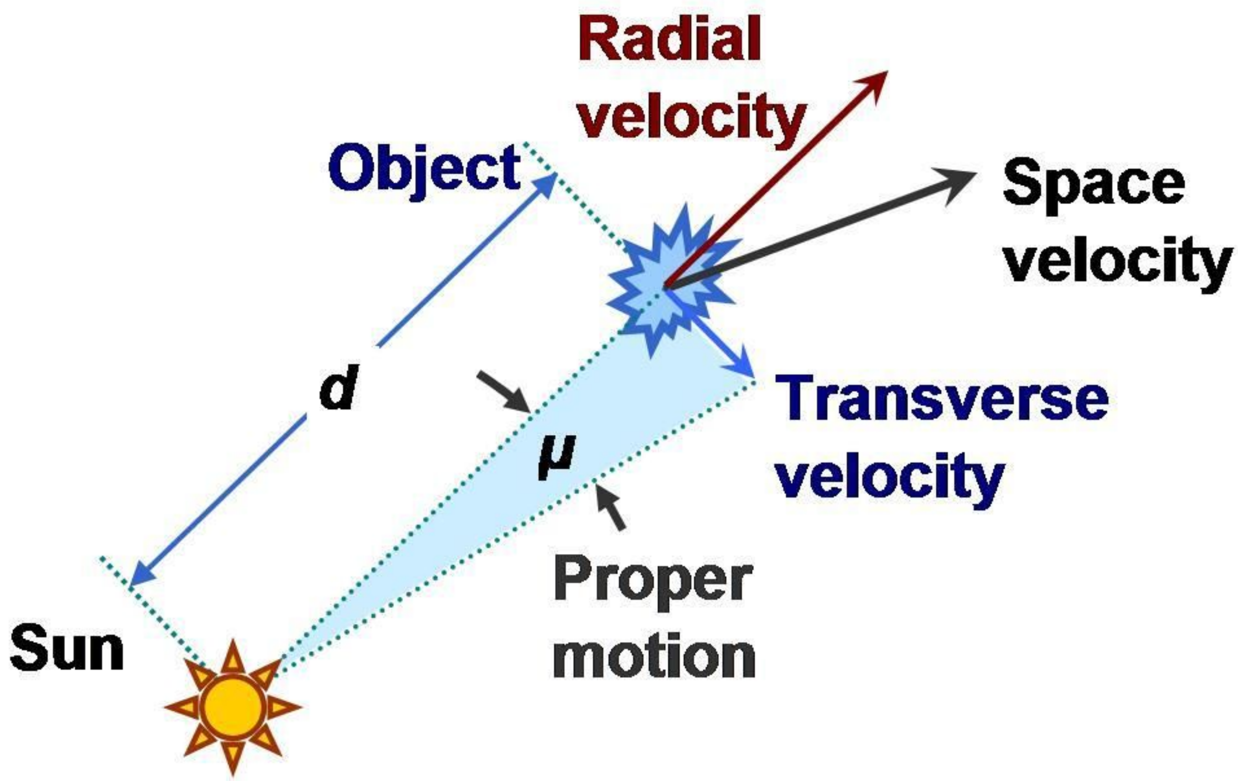
What's the brightest star you can see in the sky tonight?

If you live below 83 degrees north latitude, the brightest star in the sky is Canis Alpha Majoris, or Sirius. Seriously, (bad pun intended) the -1st magnitude star is the brightest beyond our solar system as seen from the Earth and sits high to the south on late northern hemisphere winter evenings… but has it always ruled the night?

Sure, the brightest star in the sky (next to the Sun, of course) is Sirius. 8.6 light years distant, Sirius can even be seen in the deep blue sky while the Sun is still above the horizon if you know *exactly* where to look for it. In fact, Sirius was so important to the ancient Egyptians that they based their summer calendar on its first summer sightings (known as a *heliacal rising*) at dawn.

Fun factoid: the brightest star north of the celestial equator is -0.04 magnitude Arcturus.

Remember the star Vega of *Contact* fame? Keep that name in mind, as Sirius will hand over the title of the brightest star to Vega in over 200,000 years from now.



A guide to proper motion. Credit: "Proper motion" by Brews ohare. Licensed under CC BY-SA 3.0 via Wikimedia Commons.

It all has to do with motion. Our Sun, and the solar system along with it, is moving at about 250 kilometers per second around the core of the Milky Way, completing one revolution around the galaxy about every quarter of a billion years. Think about that for a second: in the 4.5 billion year history of the Earth, we've orbited the galaxy only 18 times. A quarter of a billion years ago, the Permian-Triassic extinction event was well underway.

Feel insignificant yet? Well, in addition to our orbit around the galaxy, the solar system is also oscillating up in down through the galactic plane, taking 93 million years to travel from peak to trough. All the stars around us are in motion as well, like hurried travelers along a busy Manhattan sidewalk.

And just like people, this stellar motion is wonderfully chaotic over vast stretches of time. We see some ordinary pedestrian stars like Sirius or Alpha Centauri as bright because they're currently close by in the stellar 'hood, and some – such as Rigel and Altair – are seen as bright because they're luminous stars far away.

This is what's known as *apparent magnitude*. To make sense of the true properties of stars, astronomers refer to a star's *absolute magnitude,* or its brightness if it were placed 10 parsecs (32.6 light years) away. Place massive Deneb 10 parsecs away and it would easily be visible in the daytime with at magnitude -8.4.

The stars appear fixed in the sky during our short human life spans: Orion looks pretty much the way it did on the day you were born as the day you die. Watch the stars over centuries, however, and they slowly move with respect to our terrestrial point of view.

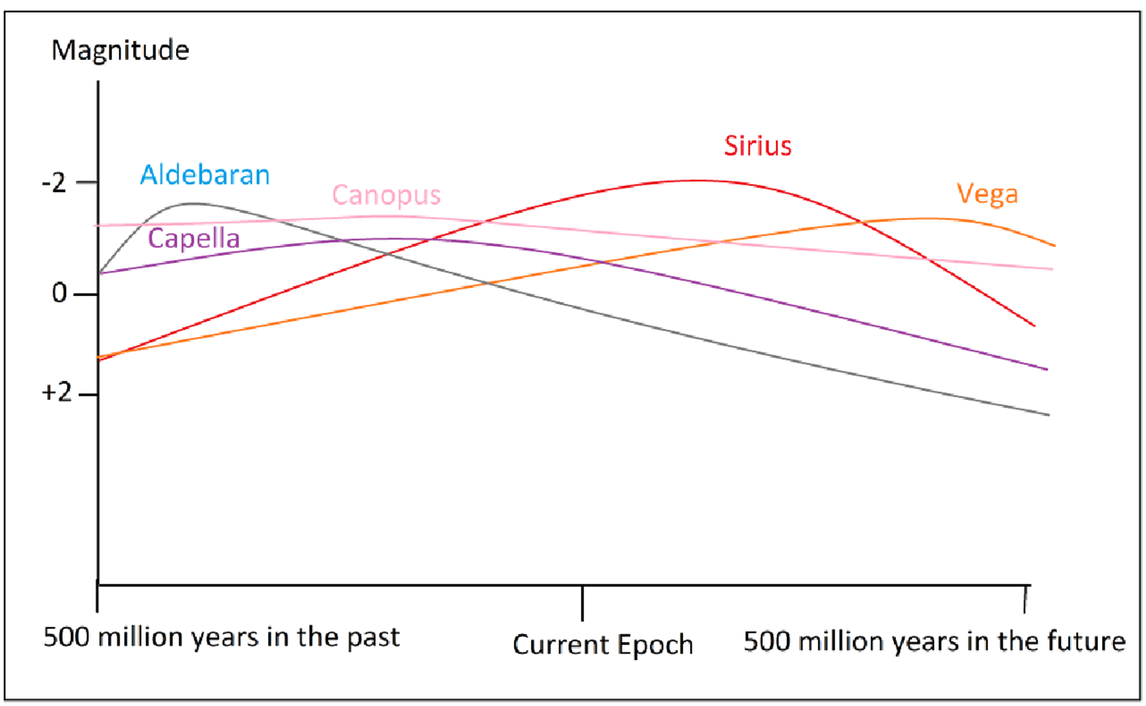
This is what's known as *proper motion*, which is a star's apparent movement across our sky. Even fast movers such as Barnard's Star or 61 Cygni only exhibit a proper motion of 10" and 3.2" arc seconds per year, respectively. Think of driving by a forest of trees: the closer trees appear to move by faster than the more distant ones. This tiny motion gave early 19th century astronomers an inkling that these 'flying stars,' though not the brightest, may be close by.

Of course, going back to the forest analogy, this motion is an illusion: 'proper' motion measures the traverse velocity along our line of sight, which is merely a product of a star's true vector through space and its radial velocity towards or away from us.

And radial motion is the key to who is 'top dog star' in the brightness game over time. Like gravity, light fades intrinsically with the inverse square of its distance. Move a candle twice as far away, and it's one fourth ($1/2^2$) as luminous.

This is actually pretty nifty, as 5 magnitudes in brightness corresponds to a hundredfold (10^2) change in luminosity. Where is it all headed? Well, we're currently moving toward the solar apex located near the star Omicron Herculis at a speed relative to local stars of 16.5 kilometers per second.

Here's a breakdown of bright stars over the our one million year epoch:

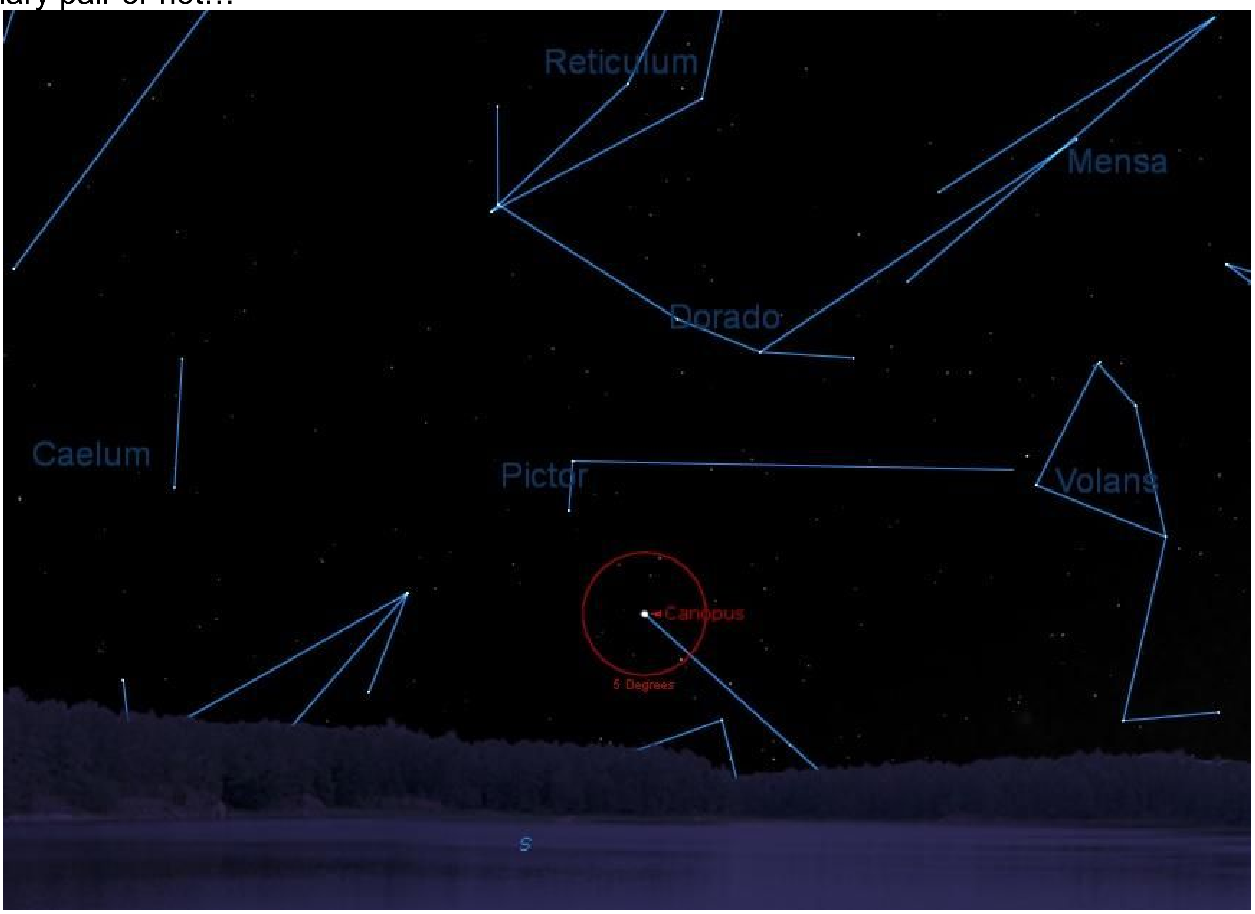


Adapted from Once and Future Celestial Kings, Sky and Telescope, April 1998.

Looking out past 1,000,000 A.D., +2.4 magnitude Delta Scuti will swell to magnitude -1.8, topping Sirius's brightness today. And waaaaay 'back in the day' circa 4.7 billion B.C., the +1.5 magnitude star Adhara (Epsilon Canis Majoris) was a chart-topping -4th magnitude, easily visible in the daytime skies of the primordial solar system.

Arcturus is another fast mover, and is currently plunging through our galactic neighborhood at a blazing 2 arc seconds per year. Arcturus reaches maximum brightness around magnitude 0 in about 4,000 years before receding and slowly fading from view.

And in the distant future, the star party fave Albireo will be 300 light years closer and shine at -0.5. Perhaps by then, those far future star party patrons will know for sure if Albireo is a true binary pair or not…



Canopus rules the night: 90,000 BC. Image credit: Starry Night.

How do we know this? Missions such as Hipparcos have measured and defined the parallax and proper motions of stars to an unprecedented degree of accuracy. Contrast this to astronomers of yore, who had to rely on wire-threaded transit instruments, a stopwatch and quick reaction time.

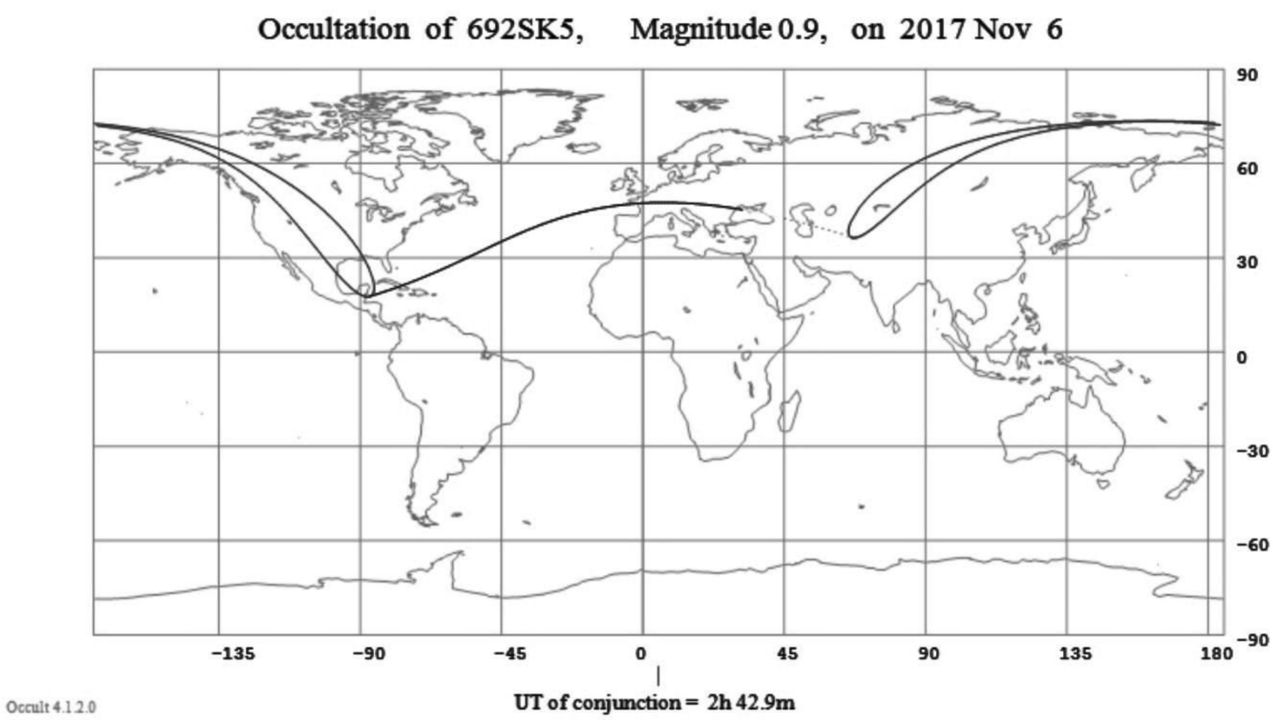
Surveys such as NEOWISE have also turned up even fainter nearby brown and red dwarf stars in their quests, and missions such as the European Space Agency's Gaia are raising our knowledge of astrometry to a new level of accuracy.

Brightest does not mean closest. Take the example of the recently discovered red dwarf Scholz's Star, which may have passed 0.8 light years from our solar system just 70,000 years ago. Even then, it may only have topped +7th magnitude in Earthly skies. And the future passage of HIP 85605 300,000 years from now at 0.5 light years distant may fair much better, at -2 magnitude. The +4.7 magnitude star Gamma Microscopii also passed within 6 light years of the Sun 3.8 million years ago, and would've shined at magnitude -3.

All great thoughts to ponder as we enjoy the night skies gracing our little epoch of space and time. Who will gaze upon those distorted skies, many million years hence?

November 2017

Monday, November 6th: The Moon occults Aldebaran



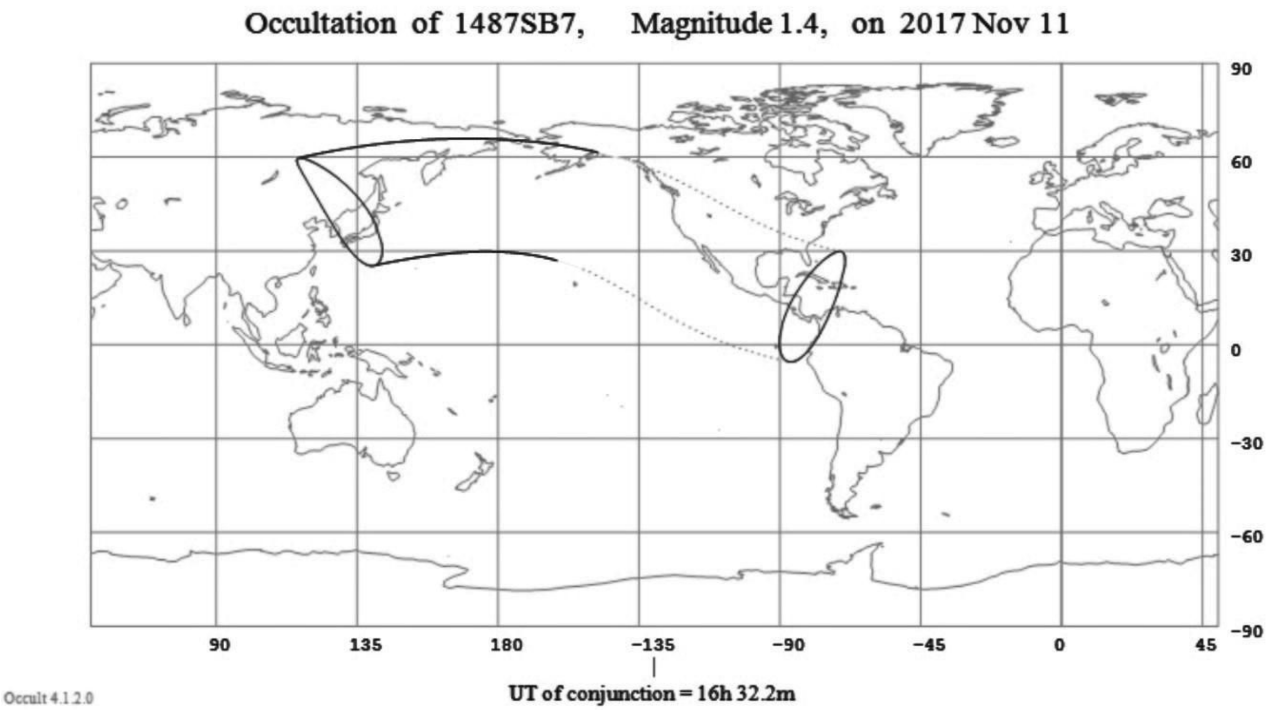
The occultation footprint for the November 6th event. Image credit: Occult 4.2.

The 95% illuminated waning gibbous Moon occults the +0.9 magnitude star Aldebaran. The Moon is 2 days past Full during the event. Both are located 153 degrees west of the Sun at the time of the event. The central time of conjunction is 2:43 Universal Time (UT). The event occurs during the daylight hours over Siberia, and under darkness for eastern North America and northern Europe, including the United Kingdom, New England and the Canadian Maritimes. The Moon will next occult Aldebaran on December 3rd. This is occultation 37 in the current series of 49 running from January 29th, 2015 to September 23rd, 2018. This is one of the best occultations of Aldebaran by the Moon for North America and Europe for 2017.

November 6th from the United Kingdom, shortly after the occultation. Image credit: Stellarium

The International Occultation Timing Association (IOTA) always welcomes recordings and observations of occultations of stars and planets by the Moon and asteroids.

Saturday, November 11th: The Moon occults Regulus



The occultation footprint of the November 11th event. Image credit Occult 4.2.

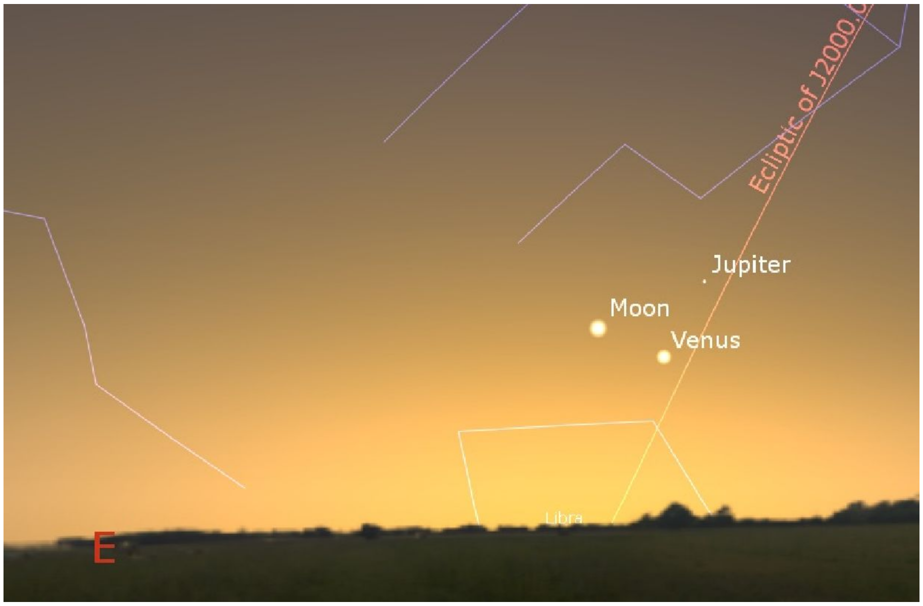
The 41% illuminated waning crescent Moon occults the +1.4 magnitude star Regulus. The Moon is 6 days from New during the event. Both are located 79 degrees west of the Sun at the time of the event. The central time of conjunction is 16:32 Universal Time (UT). The event occurs during the daylight hours over the southern and western United States, and under darkness for the northern Pacific, including the Aleutian Islands. The Moon will next occult Regulus one more final time for the year on December 8th, 2017. This is occultation 13 in the current series of 19 running from December 18th, 2016 to April 24th, 2018. This is a fine daytime event for Mexico and the southwestern United States.

Nov. 11th from Adak island, shortly after the end of the occultation. Image credit:

Stellarium.

Regulus has a close 0.3 solar mass white dwarf companion. On October 13th, 2016, David Dunham may have caught the companion star during a brief occultation of the star by the asteroid 268 Adorea. Will the white dwarf companion make an appearance during the 2016-2018 cycle of lunar occultations?

Monday, November 13th: A Close Conjunction of Venus and Jupiter



The view on November 17th, when the Moon passes the pair. Image credit: Stellarium.

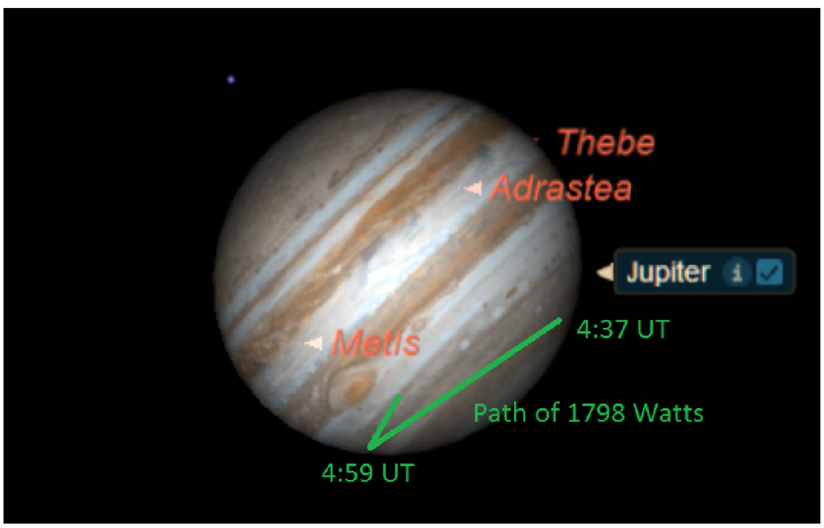
Venus and Jupiter pass within 0.3 degrees (15.7' arc minutes) of each other in a close conjunction on November 13th. Closest conjunction occurs at ~8:00 Universal Time (UT). Venus shines at -3.9 magnitude and is 10” arc seconds in diameter, and Jupiter shines at -1.7 magnitude and is 31” arc seconds in diameter at the time of closest approach. The conjunction occurs in the astronomical constellation Virgo, 14 degrees west of the Sun in the dawn. Venus is 246 million kilometers or 1.6 Astronomical Units (AU) and Jupiter is 957 million kilometers or 6.4 AU distant during the conjunction. This equates to 13 light minutes for Venus and 53 light minutes for Jupiter. The waning crescent Moon passes 3 degrees north of the pair four mornings later on the 17th.

Date	Separation	Elongation
August 18th, 2014	11.9′	18W
July 1st, 2015	20.1′	43E
October 25th, 2015	61.5′	46W
August 27th, 2016	4.0′	22E
November 13, 2017	15.7′	14W
January 22, 2019	144.4′	46W
November 24th, 2019	84.3′	26E

Close conjunctions of Venus and Jupiter from 2014 to 2019. Created by author.

This month's Jupiter/Venus conjunction is the closest since August 2016, and the nearest until January 2019. Conjunctions of Venus and Jupiter happen roughly once a year, though 2018 is 'conjunctionless' for the two planets, and 2019 has two.

Thursday, November 16th: Asteroid 1798 Watts transits Jupiter



The transit path of 1798 Watts. Image credit: Starry Night Education Software.

Asteroid 1798 Watts transits the face of the planet Jupiter from 4:37 to 4:59 Universal Time. Note that this unique event occurs just 16 degrees west elongation from the Sun in the dawn sky, and the event will be difficult to observe at best. In addition, the asteroid shines at a faint magnitude +16, while Jupiter is a -1.7 magnitude disk, 31” across. The 22 minute transit crosses a 20” long cord as seen from the Earth. 1798 Watts is 3.4 AU (506 million kilometers) distant, while Jupiter is 6.4 AU (952 million kilometers) away. The best vantage point to catch the transit is from western Europe and northwestern Africa, though the event is more than

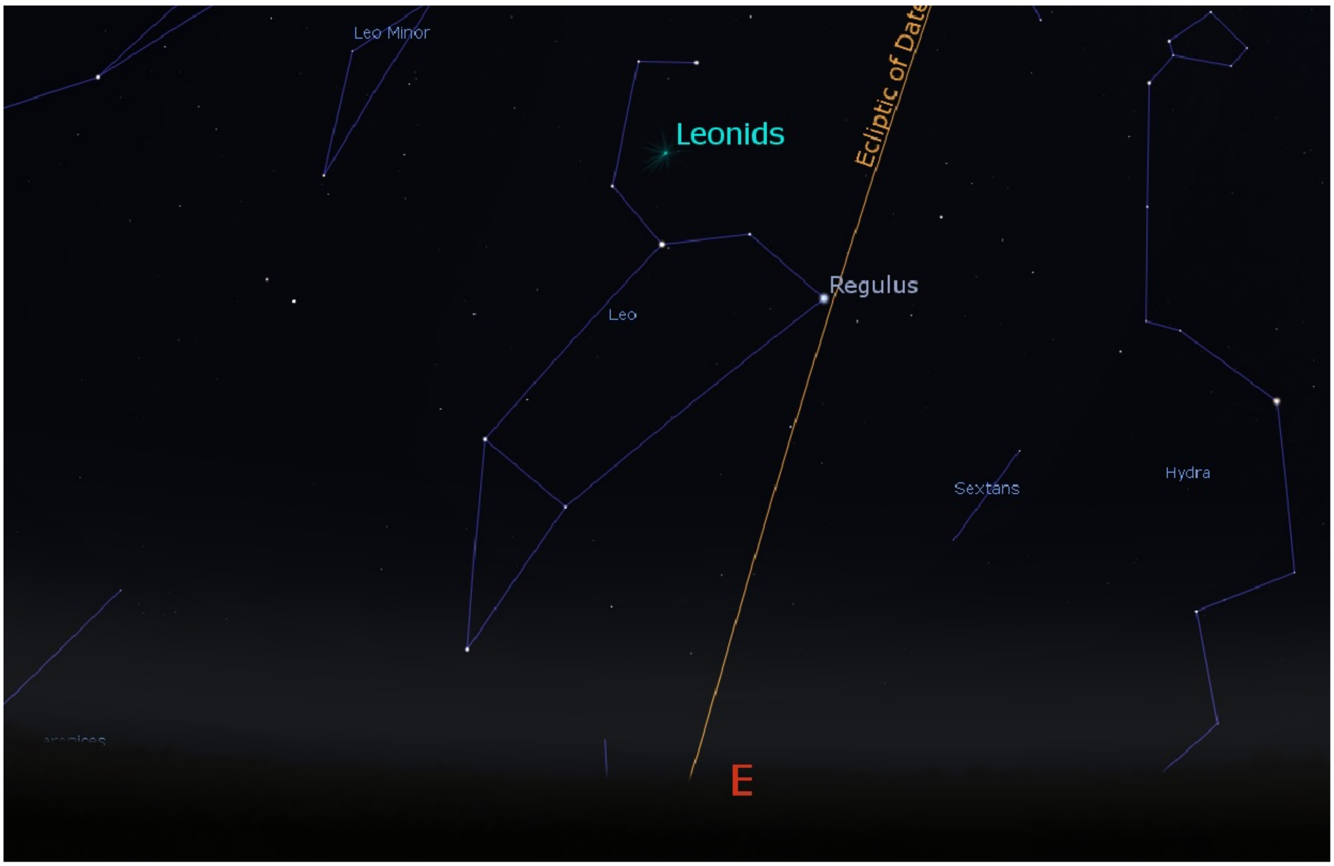
likely of pure academic rather than observational interest.

Asteroid 1798 Watts was discovered on April 4th, 1949 from the U.S. Goethe Link Observatory in Brooklyn, Indiana during the Indiana Asteroid Program survey.

Jean Meeus found 16 asteroid transits of planets as seen from the Earth spanning 2007 to 2020. The simulation considered asteroids numbered from 1 to 4000. To our knowledge, none of these difficult to observe events have been documented.

https://groups.yahoo.com/neo/groups/mpml/conversations/topics/19113

Friday, November 17th: The Leonid Meteor Shower



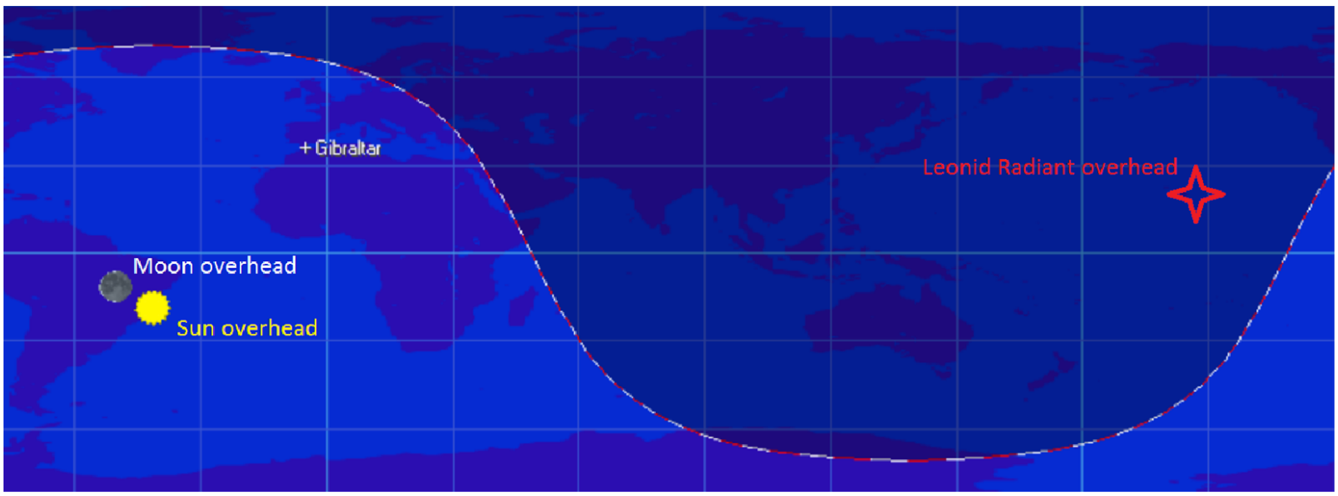
The Leonid meteor shower radiant rising on the morning of the 17th. Credit: Stellarium.

The Leonid meteors are expected to peak on November 17th at 16:30 UT, favoring Hawaii and the central Pacific. The shower is active for a three week span from November 6th to November 30th, and can vary greatly with a Zenithal Hourly Rate (ZHR) of 10 to 10,000+ meteors per hour. In 2017, the Leonids are expected to produce a maximum ideal ZHR of 10 meteors per hour. The radiant of the Leonids is located at right ascension 10 hours, 5

minutes, declination 22 degrees north at the time of the peak, in the constellation of Leo.

The Moon is a 1% illuminated waning crescent at the peak of the Leonids, making **2017 a favorable year** for this shower. In previous years, the Leonids produced a ZHR=20(2015) and a ZHR of 15 (2014).

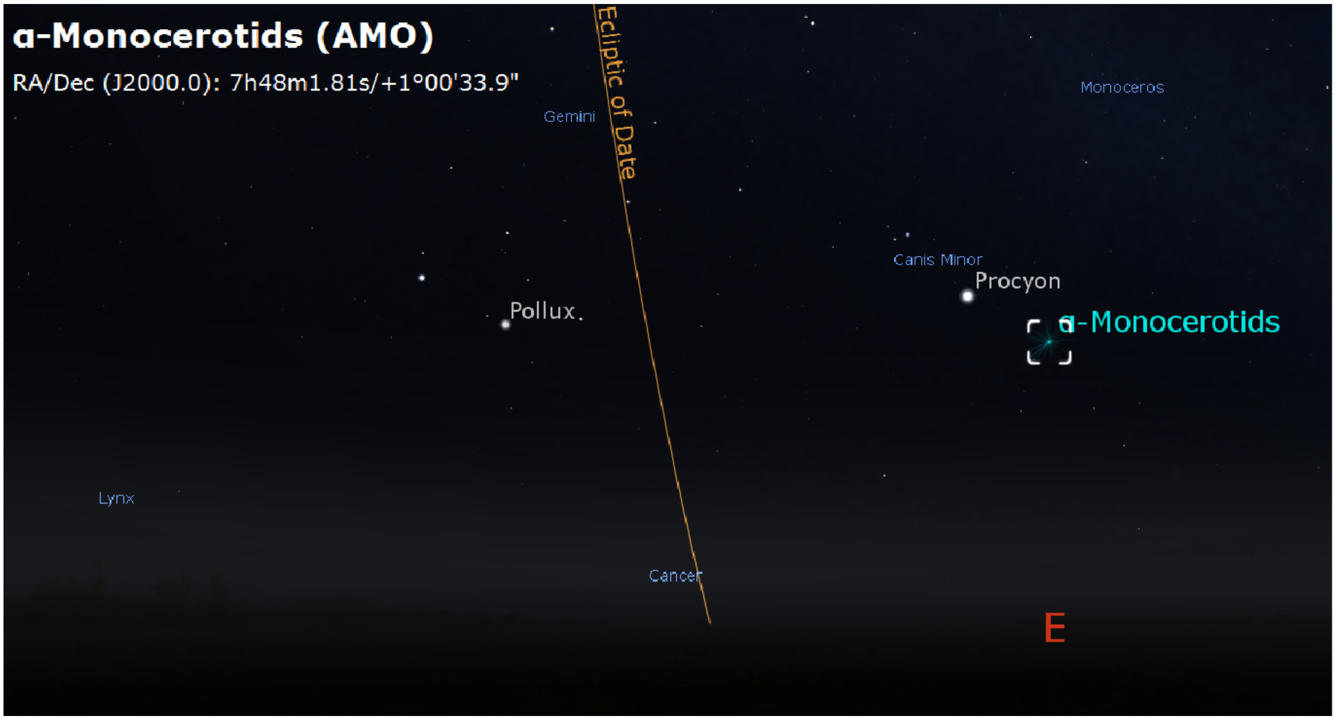
The Leonid meteors strike the Earth at a fast velocity of 71 km/s, and produce many fireballs with an *r* value of 2.5. The source of the Leonids is Comet 55P/Tempel-Tuttle. The Leonids are prone to unleashing great outbursts once every 33 years, and we're now past midway from the 1998-1999 outburst years towards the next anticipated 'Leonid meteor storm' set for 2032-2033.



The orientation of the radiant vs the Sun, Moon and Earth's shadow on November 17th at 16:30 UT. (Created using Orbitron)

Residents of the United States eastern seaboard awoke on the morning on November 13th, 1833 to a stunning sight, as meteors seemed to fill the sky like snowflakes in a winter storm. Churches filled up, as many believed the Judgment Day had dawned. In fact, great Leonid Storm of 1833 has been cited as a contributing factor to the religious fundamentalist movements of the 1830s in the United States.

Tuesday, November 21st: The Alpha Monocerotid Meteor Shower



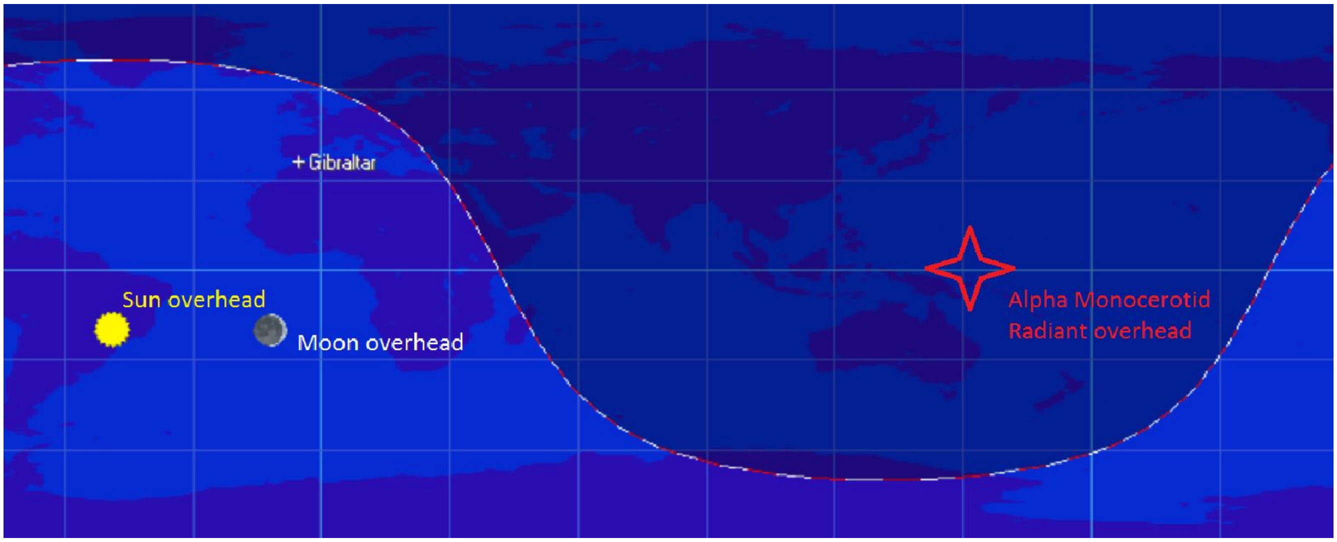
The Alpha Monocerotid meteor shower radiant on the morning of November 21st. Credit: Stellarium.

The Alpha Monocerotid meteors are expected to peak on November 21st at 17:00 UT, favoring the Coral Sea. The shower is active for a 10 day period from November 15th to the 25th, and can vary with a Zenithal Hourly Rate (ZHR) of 10 meteors per hour, with short outbursts briefly topping 400 per hour. In 2017, the Alpha Monocerotids are expected to produce a maximum ideal ZHR of 10 meteors per hour. The radiant of the Alpha Monocerotids is located at right ascension 7 hours 46 minutes, declination 0 degrees 14' north at the time of the peak, in the constellation of Monoceros.

The Moon is a 10% illuminated waxing crescent at the peak of the Alpha Monocerotids, making **2017 a favorable year** for this shower. In previous years, the Alpha Monocerotids produced short outbursts numbering in the hundreds per hour, as last occurred in 1995.

The Alpha Monocerotid meteors strike the Earth at a moderate-to-fast velocity of 65 km/s, and produce many fireballs with an *r* value of 2.4. The source of the Alpha Monocerotid meteors is an unknown long period comet. Meteor shower analyst Mikiya Sato notes that weakly enhanced rates for the Alpha Monocerotids may occur starting in 2017 through 2020. Much of just what this shower will do in the coming years depends on the November 2016 shower,

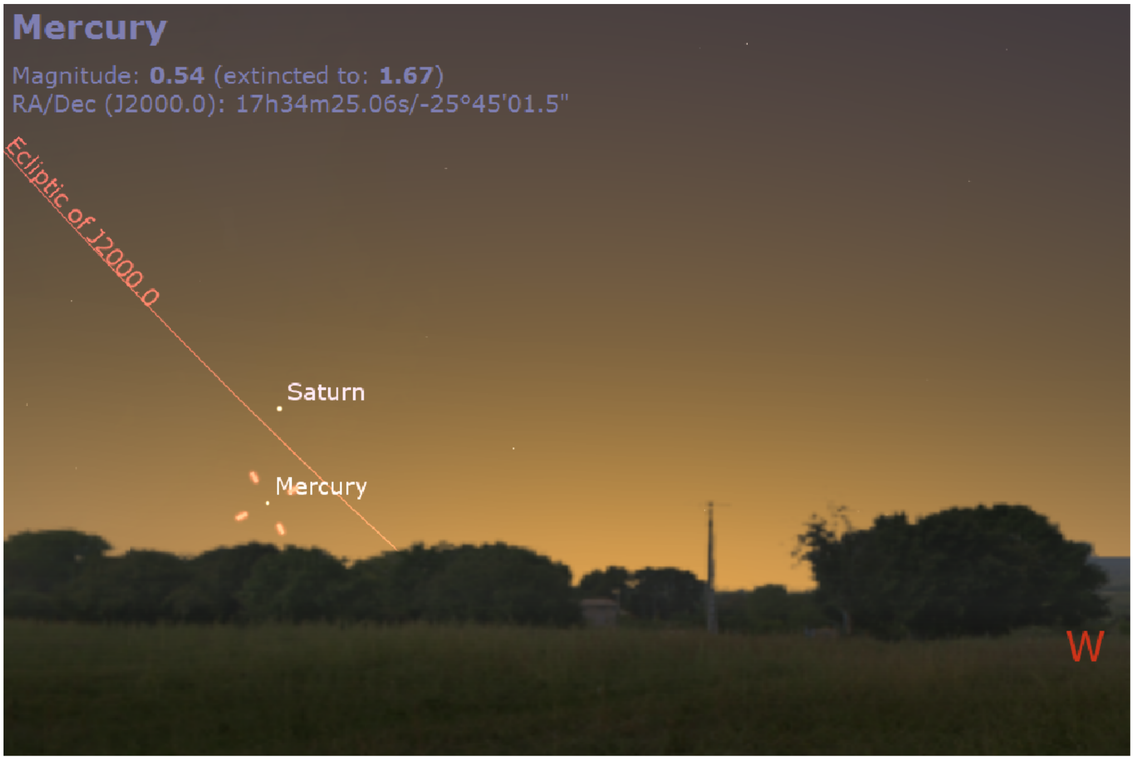
which, as of this writing, is still a month away.



The orientation of the radiant vs the Sun, Moon and Earth's shadow on November 21st at 17UT. Created by the author using Orbitron.

Another strong outburst from the Alpha Monocerotid meteors rivaling the 1995 storm is expected in 2043.

Thursday, November 23rd: Mercury reaches Greatest Elongation

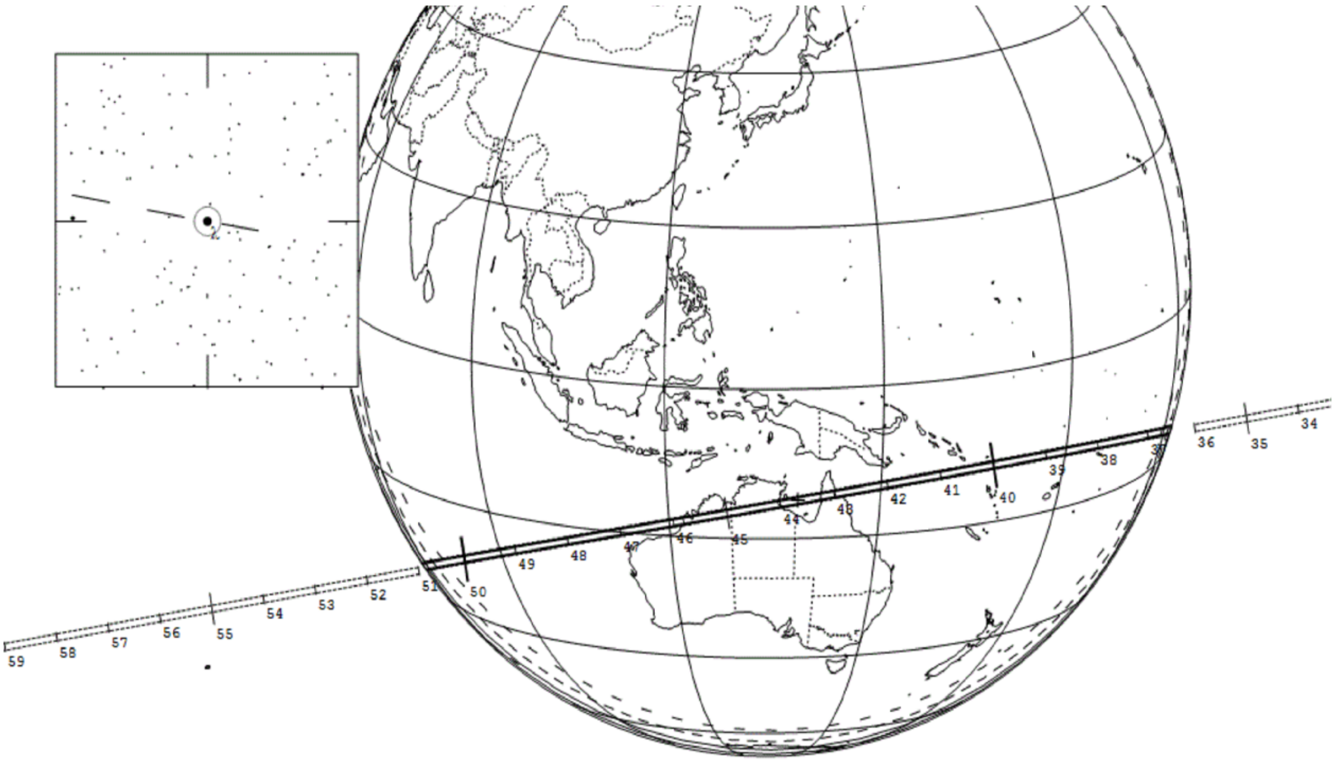


Looking west on the evening of November 23rd from latitude 30 degrees north.
Image credit: Starry Night Education Software.

The planet Mercury reaches greatest elongation 22 degrees east of the Sun in the dusk sky. The exact hour of greatest elongation occurs on November 23rd at ~18:00 Universal Time (UT). Mercury is 6.7" in apparent diameter and presents a 61% illuminated disk at greatest elongation. This is the best evening apparition of Mercury for 2017 for the southern hemisphere. Mercury then begins to head back towards the Sun every evening until reaching inferior conjunction between the Sun and the Earth on December 13th at ~1:00 UT. Mercury reaches theoretical dichotomy (half phase) on November 28th and a brilliancy of +0.5th magnitude on November 24th.. Mercury will next reach greatest western (dawn) elongation on January 1st, 2018. This is the final elongation of Mercury for 2017.

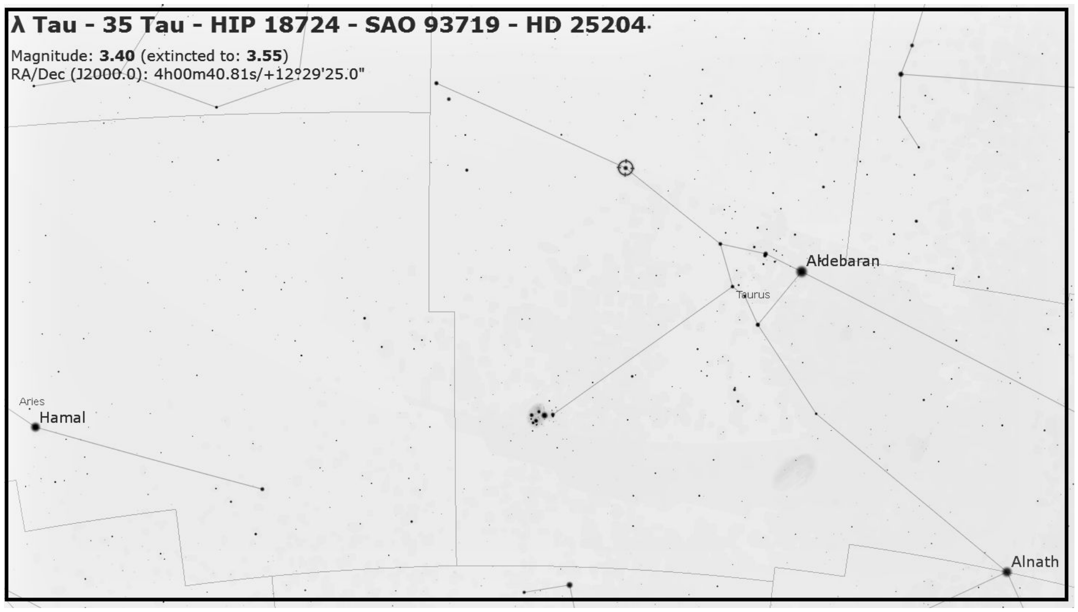
Seven elongations of Mercury occur in the calendar year 2018, the most that can occur in any year. This last occurred in 2015 and will happen again in 2022.

Sunday, November 26th: Asteroid 335 Roberta occults a Bright Star



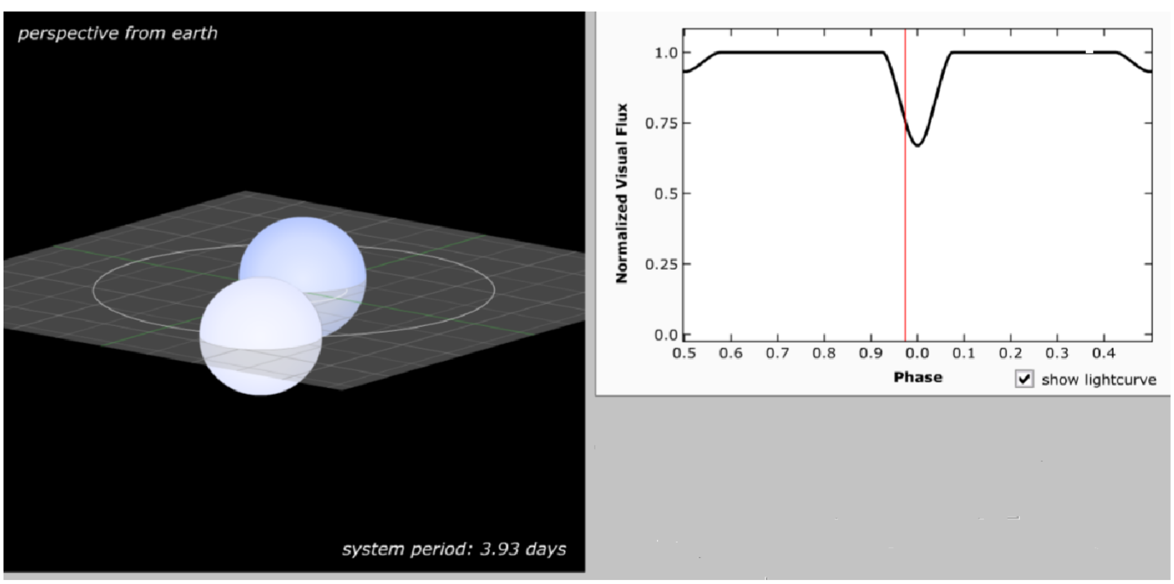
**The shadow path of 335 Roberta across Earth from 14:36 to 14:51 UT.
Image credit: Steve Preston's Best Asteroid Occultation Picks for 2017.**

Asteroid 335 Roberta occults the +3.4 magnitude star HIP 18724. The 104 kilometer-wide path crosses the Earth from 14:36 to 14:51 Universal Time (UT) on November 26th. The occultation path crosses northern Australia around 14:44 UT. The asteroid's brightness is magnitude +12.7 at the time of the event, and the occultation should last 7 seconds of maximum duration as seen from the center line. The rank for this event is 99%. The Moon is 49% waxing crescent during the event. The occulted star is located in the constellation Taurus. As seen from Limmen National Park, Australia in the Northern Territories, the occultation occurs under darkness and is 62 degrees above the horizon. Solar elongation for the occultation is 171 degrees, and the maximum expected magnitude drop is 9.3. **This is the brightest star occulted by an asteroid in 2017.**



A wide field finder chart for HIP 18724. Image credit: Stellarium.

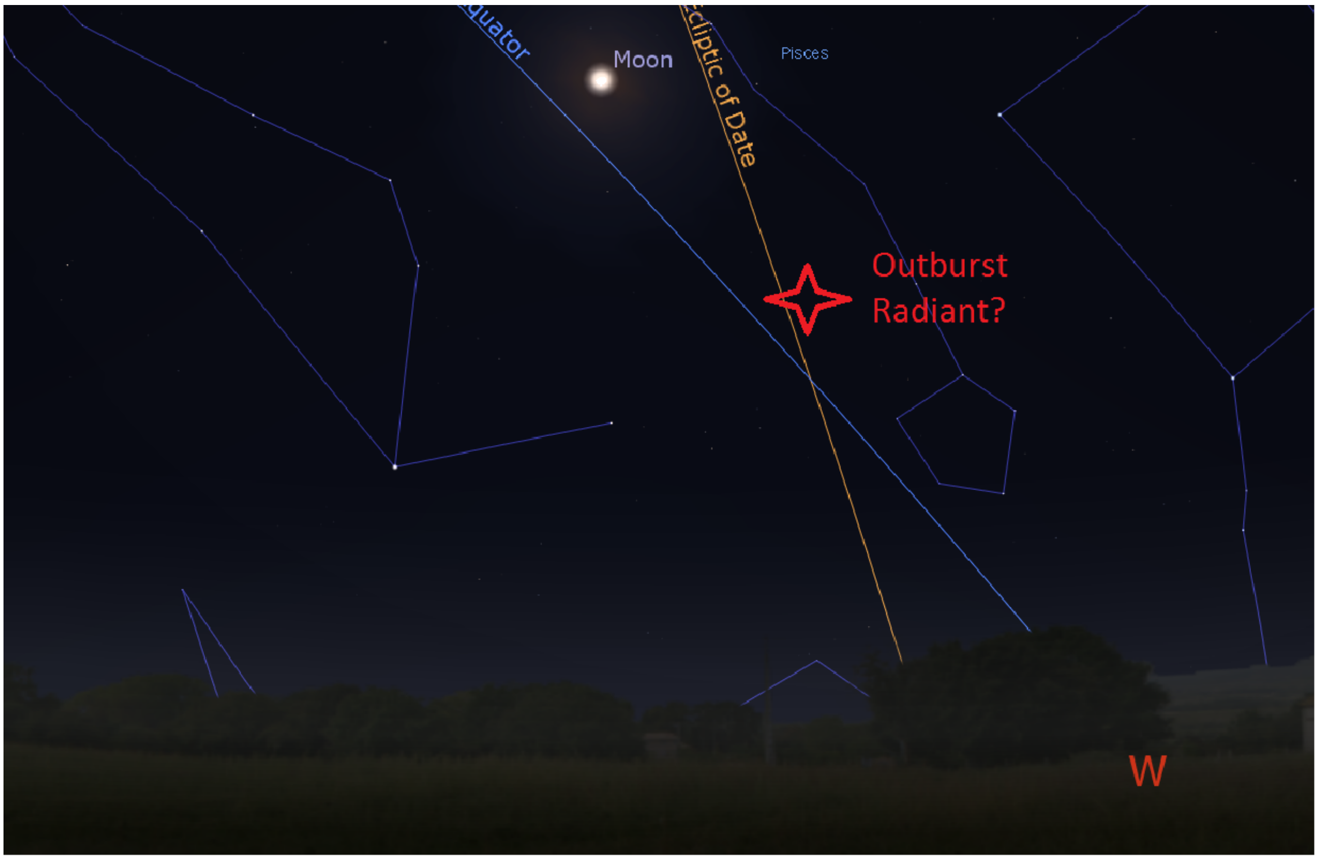
HIP 18724 is also known as Lambda Tauri, a triple binary star system. The inner two components, Lambda Tauri A and B, orbit each other once every 4 days along our line of sight, in a configuration known as an *eclipsing binary*. A third component orbits the inner two once every 33 days. Identified in 1848, Lambda Tauri was the third such eclipsing binary system discovered. The star decreases in brightness by about half a magnitude during mid-eclipse.



The orbit of eclipsing binary Lambda Tauri. Created using the U. of Nebraska-Lincoln Simulator

Lambda Tauri is 480 light years distant. Discovered on September 1st, 1892 by Anton Staus from the Heidelberg Observatory, 355 Roberta was the 12th asteroid discovered photographically, and the only asteroid discovered by Staus. 355 Roberta orbits the Sun once every 3.9 years.

Thursday, November 30th: A Meteor Outburst from Comet 46P/Wirtanen?

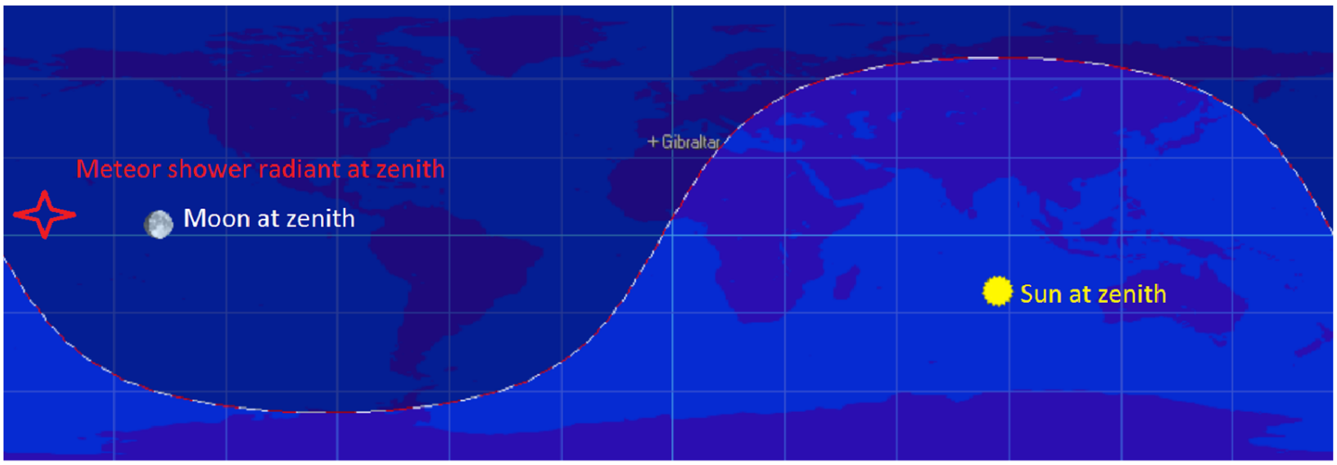


The 'Wirtanid/Piscid' meteor shower radiant on the morning of November 30th. Credit: Stellarium.

A possible outburst from periodic Comet 46/P Wirtanen may peak on November 30th at 6:00 Universal Time (UT), favoring the western Pacific. The shower could be active for several mornings from November 29th to December 1st, With an unknown Zenithal Hourly Rate (ZHR). In 2017, the mystery outburst could produce a swift and variable ZHR: some longitudes may see a brief outburst, while others may see nothing at all. The radiant of the expected Wirtanen outburst is located at right ascension 0 hours 32 minutes, declination 8 degrees north at the time of the peak in the constellation of Pisces. Perhaps, the name 'The Piscids' is a fitting one for this possible shower, not to be confused with the minor April and Delta Piscid showers.

The Moon is a 84% illuminated waning gibbous Moon is located just 20 degrees east of the radiant at the peak of the expected outburst, **an unfavorable prospect** for this possible shower.

The 'Wirtanid/Piscid' meteors will strike the Earth at a slow velocity of 14.9 km/s, as they struggle to catch up with the Earth. The should produce long, stately meteor trails. Meteor shower analyst Mikhail Maslov notes that orbital trails laid down by the comet in 1934 and 1915 pass just 0.00068 and 0.00019 astronomical units (AU) from the Earth respectively around November 30th.



The orientation of the radiant vs the Sun, Moon and Earth's shadow on November 30th at 6:00 UT. Created using Orbitron.

Short period Comet 46/P Wirtanen orbits the Sun once every 5.43 years.

Astronomy in 2018: A Teaser

Here's what we're keeping our eye to the sky for in the coming year

Astronomy doesn't stop on December 31st. There's another exciting calendar year ahead. Here's a a brief look at what we're watching for in 2018:

-Eclipses:

Three each partial solar eclipses, Plus two total lunar eclipses, including the first total lunar eclipse for North America since 2015 on January 31st, 2018 (also a 'Blue Moon').

-Mars at Opposition:

The Red Planet reaches a favorable opposition in late July, one that will be very nearly as good as the historic 2003 opposition.

-A possible Draconid outburst?

This shower is so-so on most years, but we may be in for a meteor storm in early October 2018.

Final occultations of Aldebaran and Regulus:

Occultations of the two bright stars wrap up in 2018.

-The Deepening Solar Minimum:

Will Sol continue to underperform as we plod towards solar minimum?

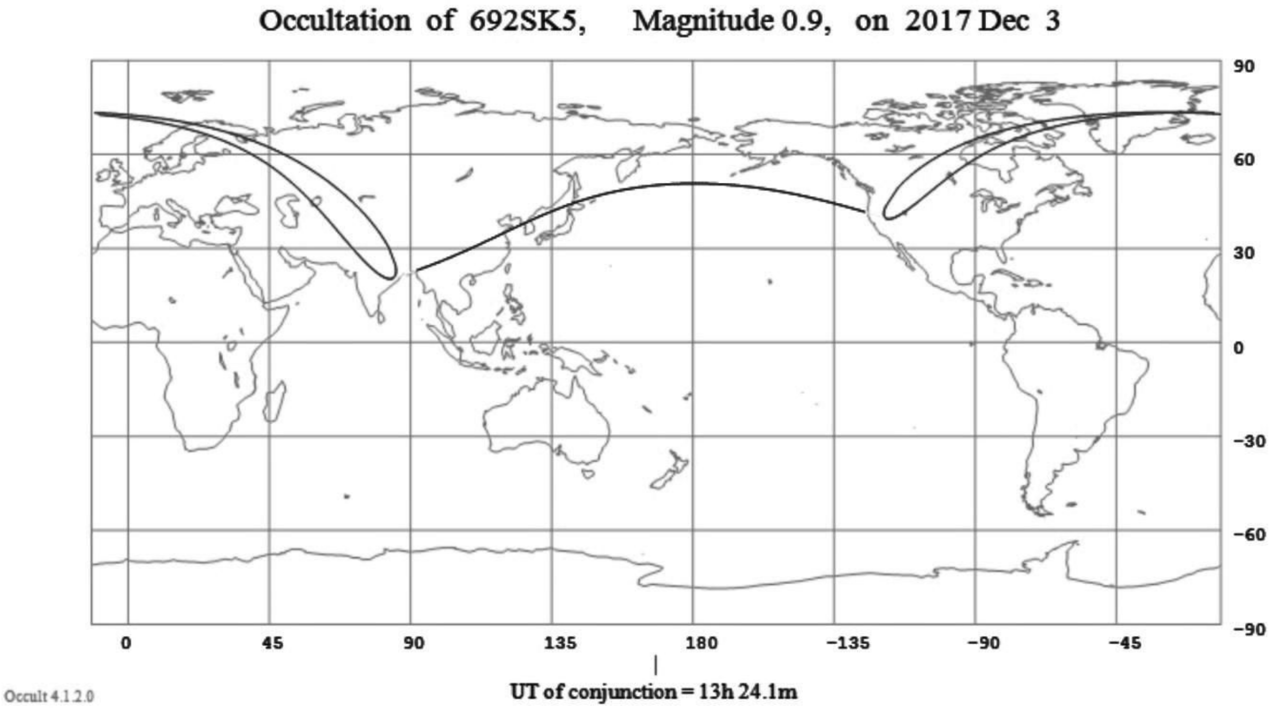
-Comet Wirtanen:

A fine periodic binocular comet... and hey, we're 'due' for the next big bright 'comet of the century..."

Like this guide? Have any inputs or suggestions for the coming year? Drop us a line at *Universe Today* or on Twitter (we're @Astroguyz)... this year's guide was a sort of experiment, but we're willing to expand it further in 2018 if there's sufficient interest!

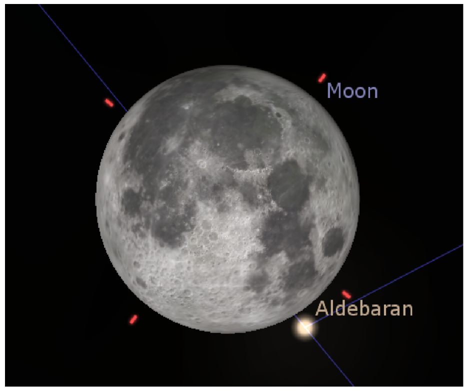
December 2017

Sunday, December 3rd: The Moon occults Aldebaran



The footprint of the December 3rd event. Image credit Occult: 4.2.

The 99.8% illuminated waxing gibbous (nearly Full) Moon occults the +0.9 magnitude star Aldebaran. The Moon is just over 3 hours from Full during the event. Both are located 174 degrees east of the Sun at the time of the event. The central time of conjunction is 13:24 Universal Time (UT). The event occurs during the twilight hours hours over northeast India and the northwestern United States, and under darkness across northeastern Asia and northwestern North America, including Alaska and Japan. The Moon will next occult Aldebaran for one final time in 2017 on December 31st. This is occultation 38 in the current series of 49 running from January 29th, 2015 to September 23rd, 2018. The penultimate occultation of Aldebaran for 2017, this is also the closest bright star occultation near Full Moon for 2017, and also occurs nearly squarely over the nighttime side of the Earth.



The view on December 3rd from southern Alaska. Image credit: Stellarium

Aldebaran has a tiny but discernible angular diameter of 20 milliarcseconds, equivalent to a 40 meter diameter crater as seen at the Moon's distance.

Monday, December 4th: A Super Moon

The 2016 Supermoon setting behind the Moor Castle in Jimena de la Frontera, Spain. Photo by Author.

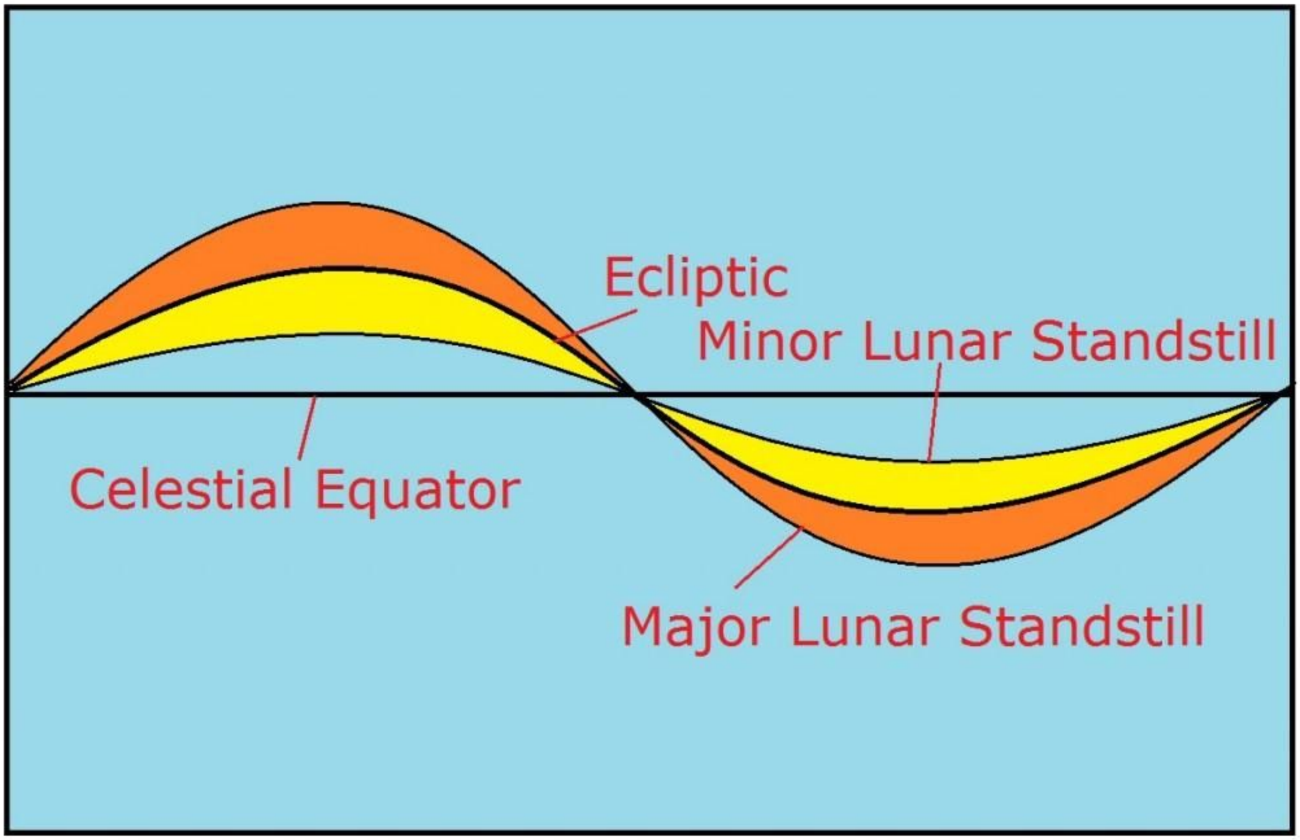
A Super Full Moon occurs. Like Blue and Black Moons, this is more of a cultural phenomenon than a true astronomical event. The Moon's orbit is elliptical, taking it from 362,600 to 405,400 km from the Earth in the course of its 27.55 day anomalistic orbit from one perigee to the next. For the purposes of this guide, we consider a 'Supermoon' as when the Full Moon occurs within 24 hours of perigee, and a 'Minimoon' as when the Full Moon occurs within 24 hours of apogee. From the Earth, the Moon varies in apparent size from 29.3” to 34.1” across. The Moon reaches perigee on December 4th at 8:43 Universal Time (UT) at 357,495

kilometers distant, 16 hours and 54 minutes after reaching Full phase on December 3rd. This is the second closest perigee of 2017 by 286 kilometers and the final perigee and final Full Moon of 2017.

Unlike all other planetary satellites in the solar system, the orbit of the Earth's Moon is not fixed relative to the primary planet's equator, but to the ecliptic plane.

Tuesday, December 5th: The Most Northerly Moon for 2017

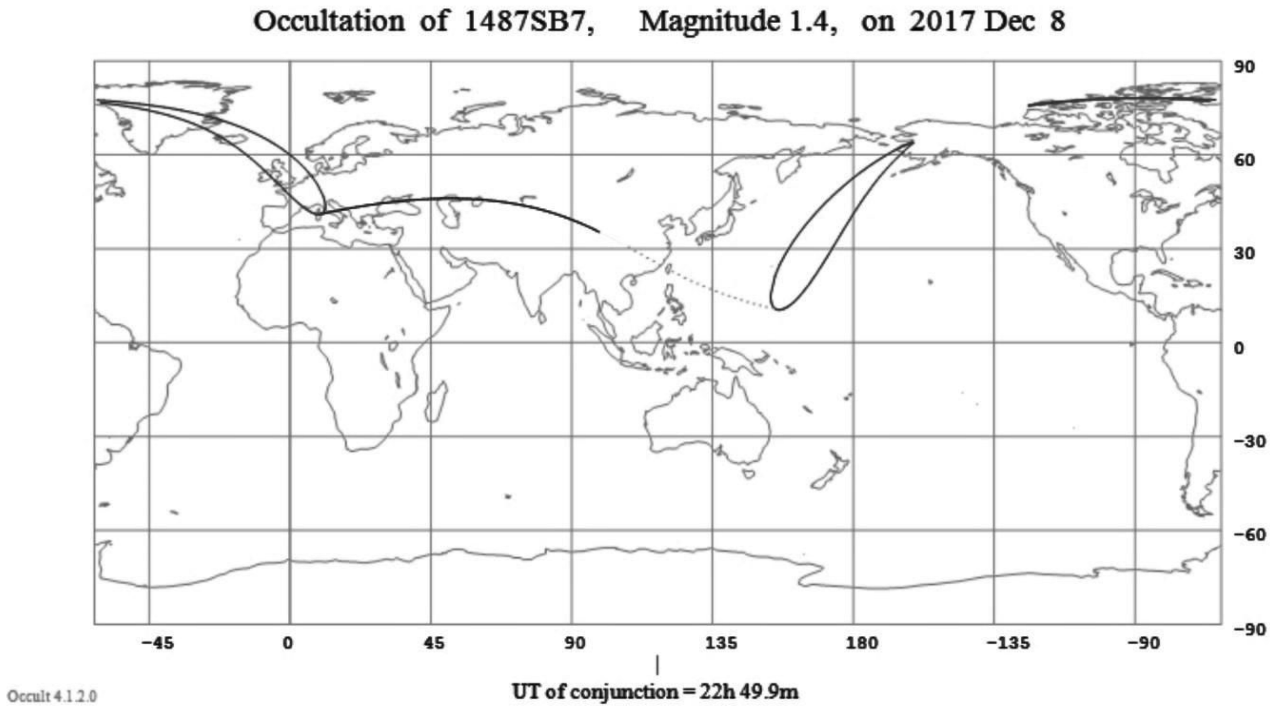
The Moon reaches its most northerly declination for 2017. This occurs on December 5th at ~11:00 Universal Time (UT), when the Moon reaches a declination of +20.0 degrees north. The Moon passes directly through the zenith as seen from the southern tip of the Baja California peninsula at this time. The Moon is 95% waning gibbous phase on this date. 2017 is the last of the 'shallow year' for the Moon's path relative to the ecliptic as we passed a hilly year (known as a *minor lunar standstill*) in 2015, and are now headed towards a major lunar standstill and a 'hilly year' maximum in 2025. 2018 leading up to 2021 will be 'ecliptic-like' years. This cycle repeats every 18.6 years, as the path of the Moon varies from declination 18.1 to 28.7 degrees south to north.



The apparent path of the Moon during 'shallow' versus 'hilly' years.
Graphic by author.

The Full Moon closest to the December southward solstice is sometimes known as the Yule or Long Night's Moon.

Friday, December 8th: The Moon occults Regulus



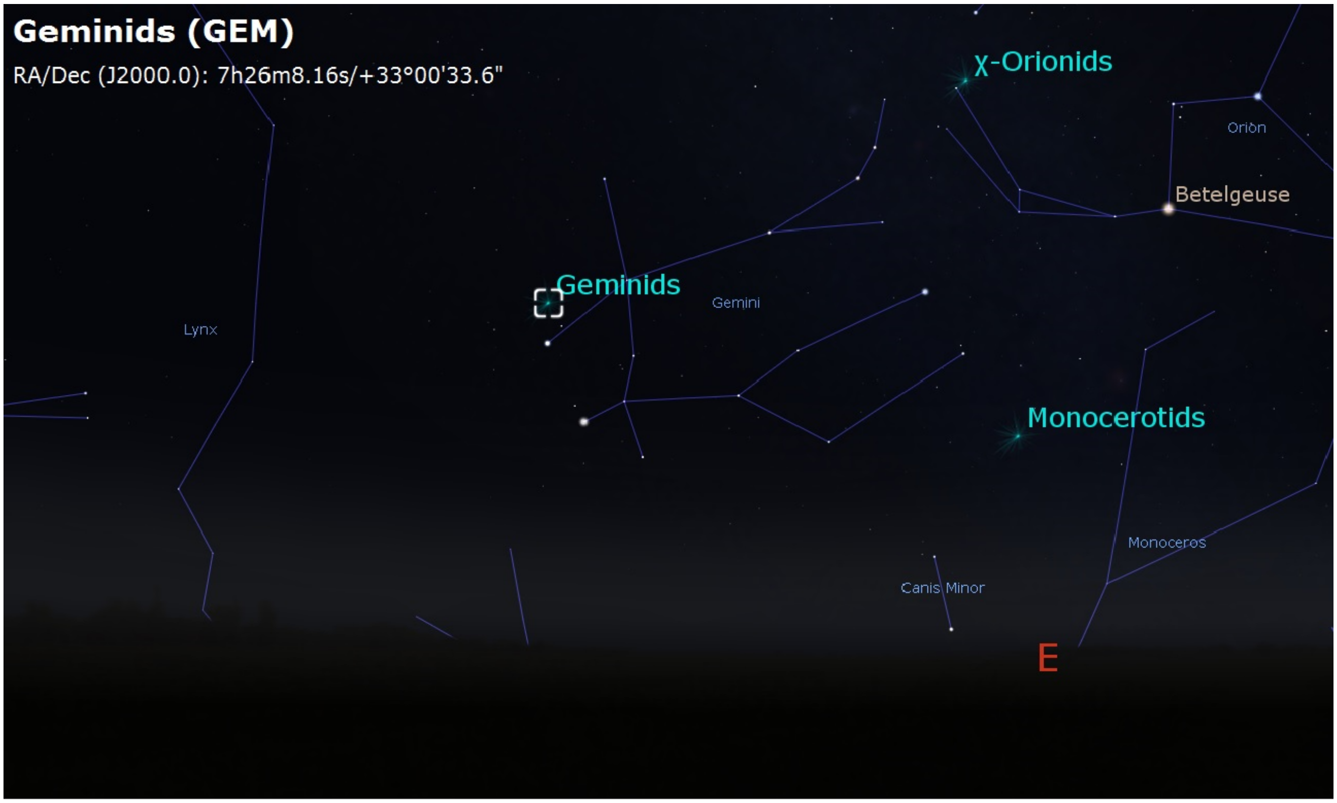
The occultation footprint for the December 8th event. Image credit: Occult 4.2.

The 65% illuminated waning gibbous Moon occults the +1.4 magnitude star Regulus. The Moon is 5 days past Full during the event. Both are located 107 degrees west of the Sun at the time of the event. The central time of conjunction is 22:50 Universal Time (UT). The event occurs during the daylight hours over Japan and the Far East, and under darkness for Europe, including Scandinavia. The Moon will next occult Regulus on January 5th, 2018. This is occultation 14 in the current series of 19 running from December 18th, 2016 to April 24th, 2018. This is the final occultation of Regulus for 2017.

The view on December 8th from Scandinavia. Image credit: Stellarium.

After 2018, the Moon won't occult Regulus again until mid-2025.

Thursday, December 14th: The Geminid Meteor Shower



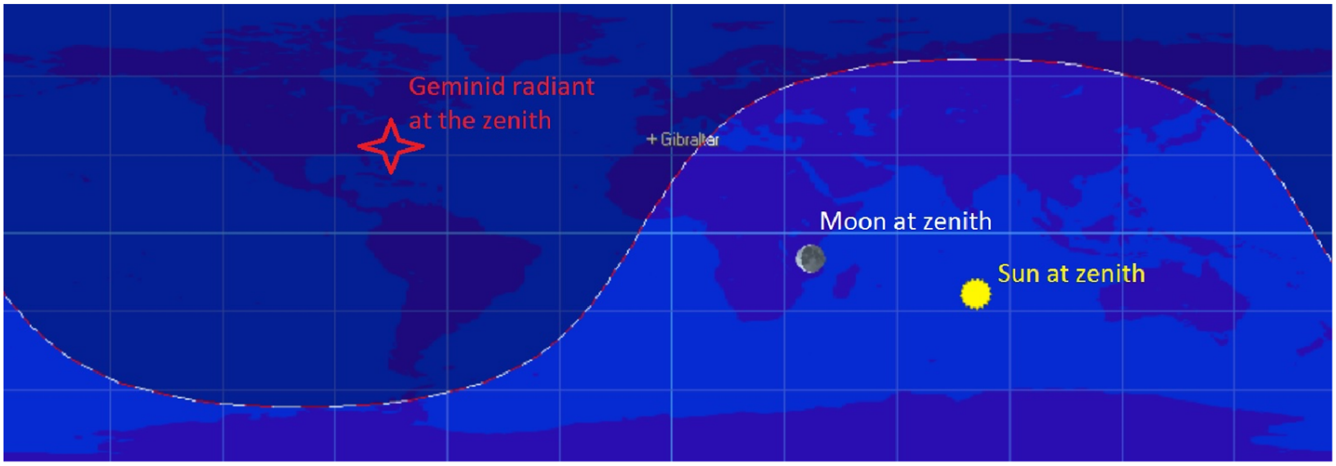
The Geminid meteor shower radiant on the evening of December 13th. Credit: Stellarium.

The Geminid meteors are expected to peak on December 14th at 6:30 Universal Time (UT), favoring North America. The shower is active for a two week period from December 4th to December 17th and can vary with a Zenithal Hourly Rate (ZHR) of 60 to 200 meteors per hour, with short outbursts briefly topping several hundred per hour. In 2017, the Geminids are expected to produce a maximum ideal ZHR of 120 meteors per hour. The radiant of the Geminids is located at right ascension 7 hours 26 minutes, declination 33 degrees north at the time of the peak, in the constellation of Gemini the Twins.

The Moon is a 16% illuminated waning crescent at the peak of the Geminids, making 2017 **a favorable** for this shower. In previous years, the Geminids produced a ZHR of 185 in 2015 and 253 in 2014.

The Geminid meteors strike the Earth at a slow velocity of 35 km/s, and produce many

fireballs with an *r* value of 2.6. The source of the Geminid meteors is actually an asteroid: 3200 Phaethon. In recent years, the Geminids have surpassed the Perseids, the year's other most dependable shower in terms of intensity.



The orientation of the radiant vs the Sun, Moon and Earth's shadow on December 14th at 06:30 UT. (Created using Orbitron)

Unlike most meteor showers, the radiant of the Geminids is located high enough northward in December to begin producing observable activity well before local midnight.

Tuesday, December 19th: Most Southerly Moon for 2017

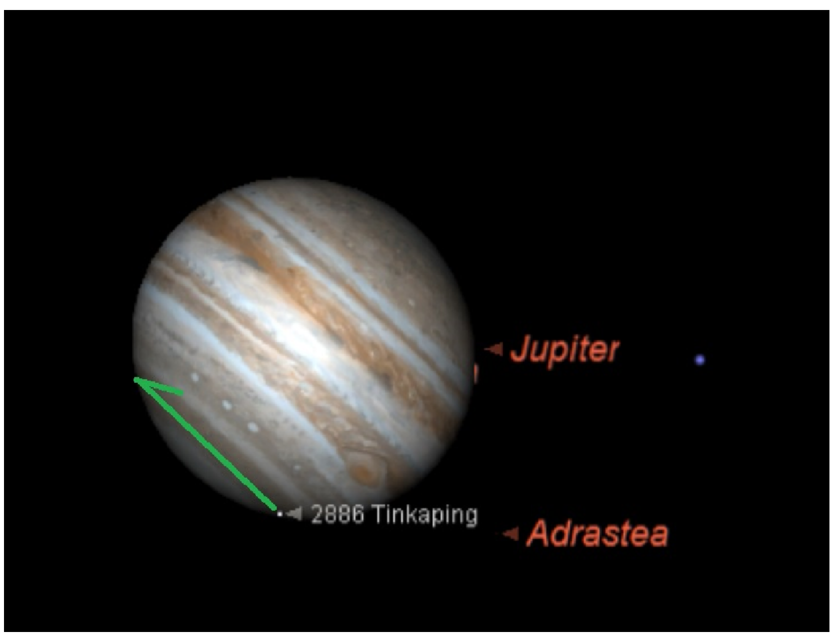
The Moon reaches its most southerly declination for 2017. This occurs on December 19th at 9:00 Universal Time (UT), when the Moon reaches a declination of 20.1 degrees south. The Moon passes directly through the zenith as seen from the central Indian Ocean at this time. The Moon is 1.2% waxing crescent phase on this date. 2017 is the last of the 'shallow year' for the Moon's path relative to the ecliptic as we passed a hilly year (known as a minor lunar standstill) in 2015, and are now headed towards a major lunar standstill and a 'hilly year' maximum in 2025. 2018 leading up to 2021 will be 'ecliptic-like' years. This cycle repeats every 18.6 years, as the path of the Moon varies from declination 18.1 to 28.7 degrees south to north.

Lunar standstills for the first half of the 21st century			
Type	Node crossing	Actual Dates	Declination
Major	June 20, 2006	March 22/September 15	+/-28.7
Minor	October 9, 2015	September 21/October 3	+/-18.1
Major	January 29, 2025	March 7/March 22	+/-28.7
Minor	May 21, 2034	March 13/March 26	+/-18.1
Major	September, 10, 2043	September 12/September25	+/-28.7

Aspects of major a minor lunar standstill years. Node crossing refers to the date that the ascending/descending node of the Moon equals an ecliptic value of zero, while the actual dates refer to the times of greatest declination. Credit: Dave Dickinson.

The Moon can actually transit 18 astronomical constellations: the traditional 12 constellations of the zodiac, plus Orion, Ophiuchus, Auriga, Cetus, Corvus, and Sextans.

Tuesday, December 19th: Asteroid 2886 Tinkaping transits Jupiter



The transit of 2886 Tinkaping. Image credit: Starry Night Education Software.

Asteroid 2886 Tinkaping transits the face of the planet Jupiter from 19:30 to 20:03 Universal Time (UT). This unique event occurs 43 degrees west elongation from the Sun in the dawn sky, and the event will be difficult to observe at best, owing to the high magnitude contrasts

between the planet and the asteroid: the asteroid shines at a faint magnitude +17, while Jupiter is a -1.8 magnitude disk, 32" across. The 33 minute transit crosses a 16" long cord as seen from the Earth. 2886 Tinkaping is 3.2 AU (476 million kilometers) distant, while Jupiter is .6.1 AU (908 million kilometers) away. The best vantage point to catch the transit is from Japan, Australia and New Zealand, though the event is more than likely of pure academic rather than observational interest.

Astronomers observing from the Purple Mountain Observatory in Nanjing, China discovered asteroid 2886 Tinkaping on the night of December 20th, 1965. Provisionally named 1965 YG, the asteroid was later named after Japanese businessman and educational patron Tin Ka Ping.

Jean Meeus found 16 asteroid transits of planets as seen from the Earth spanning 2007 to 2020. The simulation considered asteroids numbered from 1 to 4000. To our knowledge, none of these difficult to observe events have been documented.

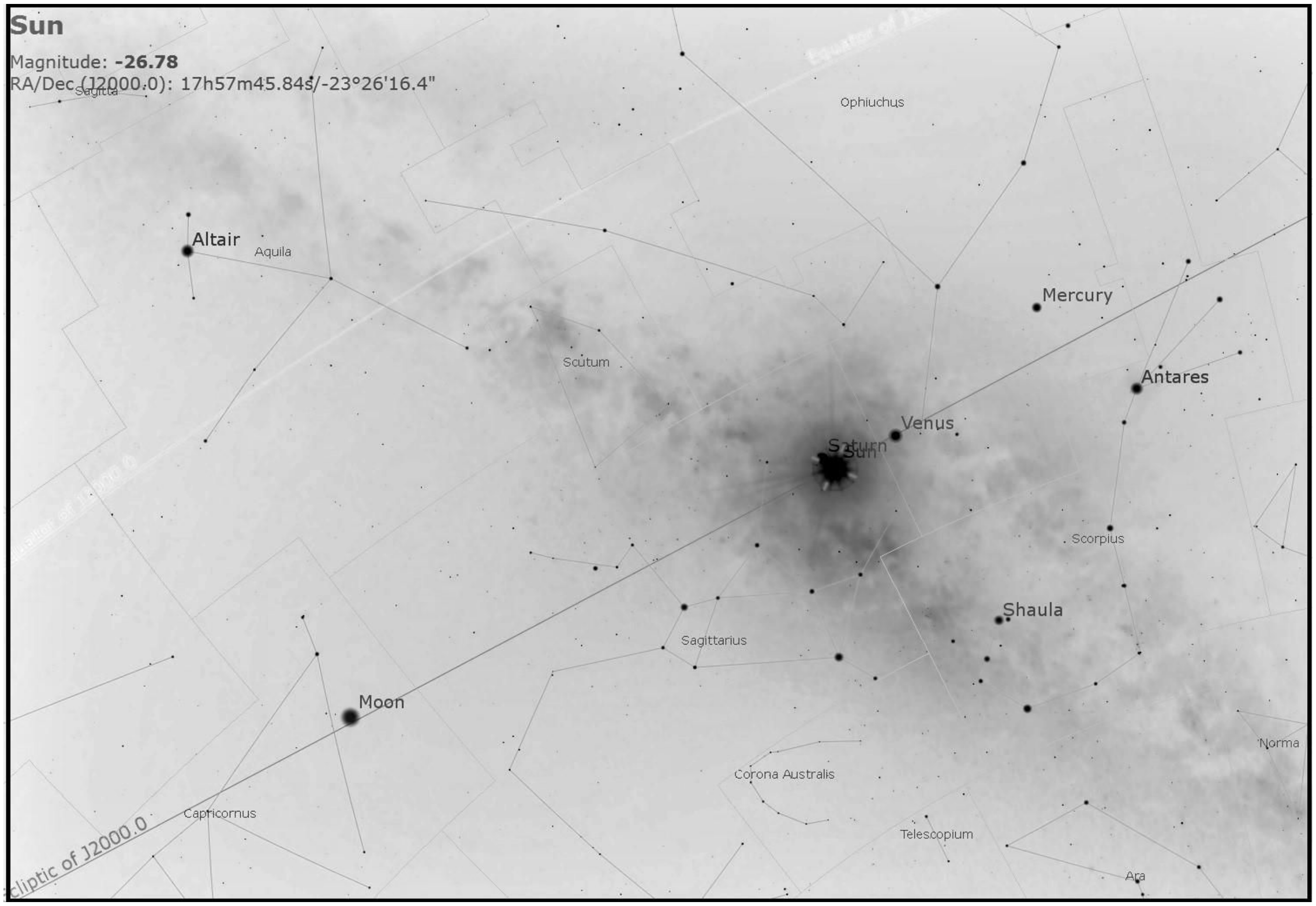
https://groups.yahoo.com/neo/groups/mpml/conversations/topics/19113

Tuesday, December 19th: The Most Distant Lunar Apogee of the Year

The Moon reaches its most distant apogee of 2017. The moment of apogee occurs at 1:28 Universal Time (UT), during which the Moon will reach its farthest point, appearing at the zenith or directly overhead for the Coral Sea. The Moon is a waxing crescent, 0.6% illuminated and in the astronomical constellation of Sagittarius at apogee. This occurs just 18 hours and 57 minutes past New on December 18th. The Moon reaches apogee 13 times in 2017, ranging from 404,305 kilometers (closest on August 30th) to 406,604 kilometers on December 19th. The Moon appears 29' 30" across at apogee, versus the typical appearance of 34' 06" across at perigee. The closest apogee for the 21st century is 404,051 kilometers on July 26th, 2069, and the most distant apogee for the century is 406,709 kilometers distant on December 12th, 2061.

The Moon is slowly receding from the Earth, at a rate of 3.8 centimeters a year.

Thursday, December 21st: The December Solstice



A 'Black Hole Sun' on the December Solstice. Image credit: Stellarium.

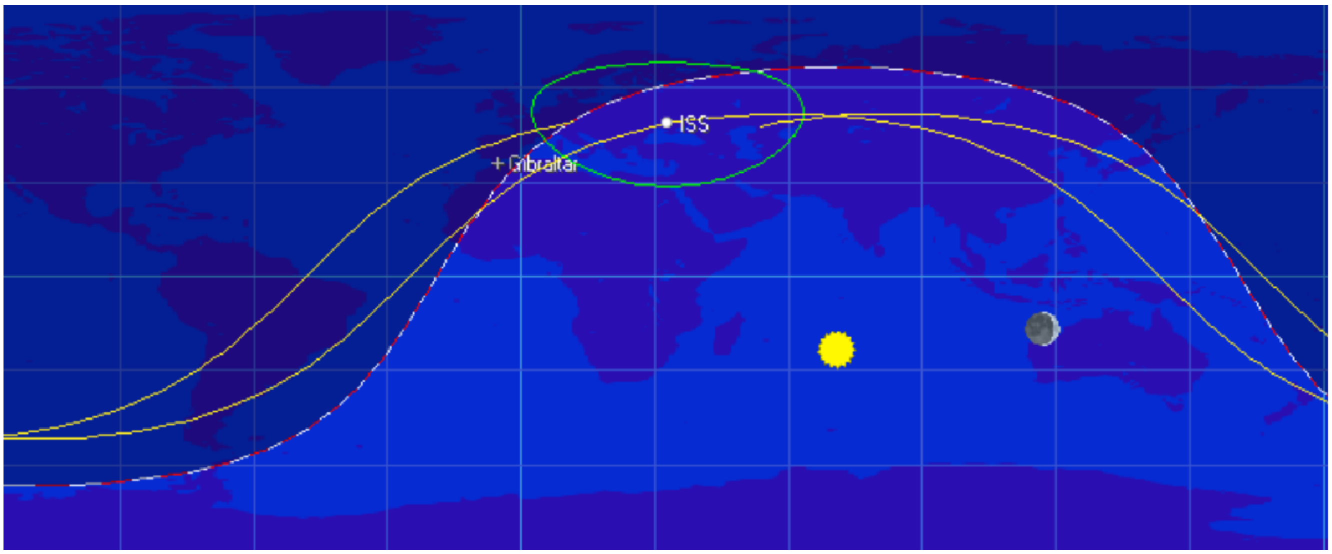
The southward solstice occurs at 16:28 Universal Time (UT), marking the beginning of astronomical winter for the northern hemisphere, and the start of summer for the southern. This is an exact moment when the Sun's declination equals 23.5 degrees south as seen from the Earth. The line of latitude where the Sun passes directly overhead during the December solstice is known as the Tropic of Capricorn, although in modern times, the Sun is in the astronomical constellation of Sagittarius in mid-December. Thanks to precession.

In the 21st century, the December solstice will fall on the 21st and the 22nd until 2043, and will start occasionally falling on December 20th in 2080.

The solstice (meaning 'stationary Sun' in Latin) means that the southern rotational pole of the Earth is now tipped towards the Sun, which will now begin its long apparent journey northward again until June. In 2017, latest sunrise actually occurs on January 6th (8:44 AM local) and earliest sunset occurs on December 6th (5:56 PM local) as seen from latitude 40

degrees north. The wobble of Earth's axis known as the Precession of the Equinoxes takes about 26,000 years to complete one 'wobble.' Live out an average 72 year life span, and the equinoctial points will have moved one degree (about twice the diameter of a Full Moon).

Friday, December 22nd: The International Space Station Enters Full Illumination



Full illumination of the ISS along the length of its orbit. Image credit: Orbitron.

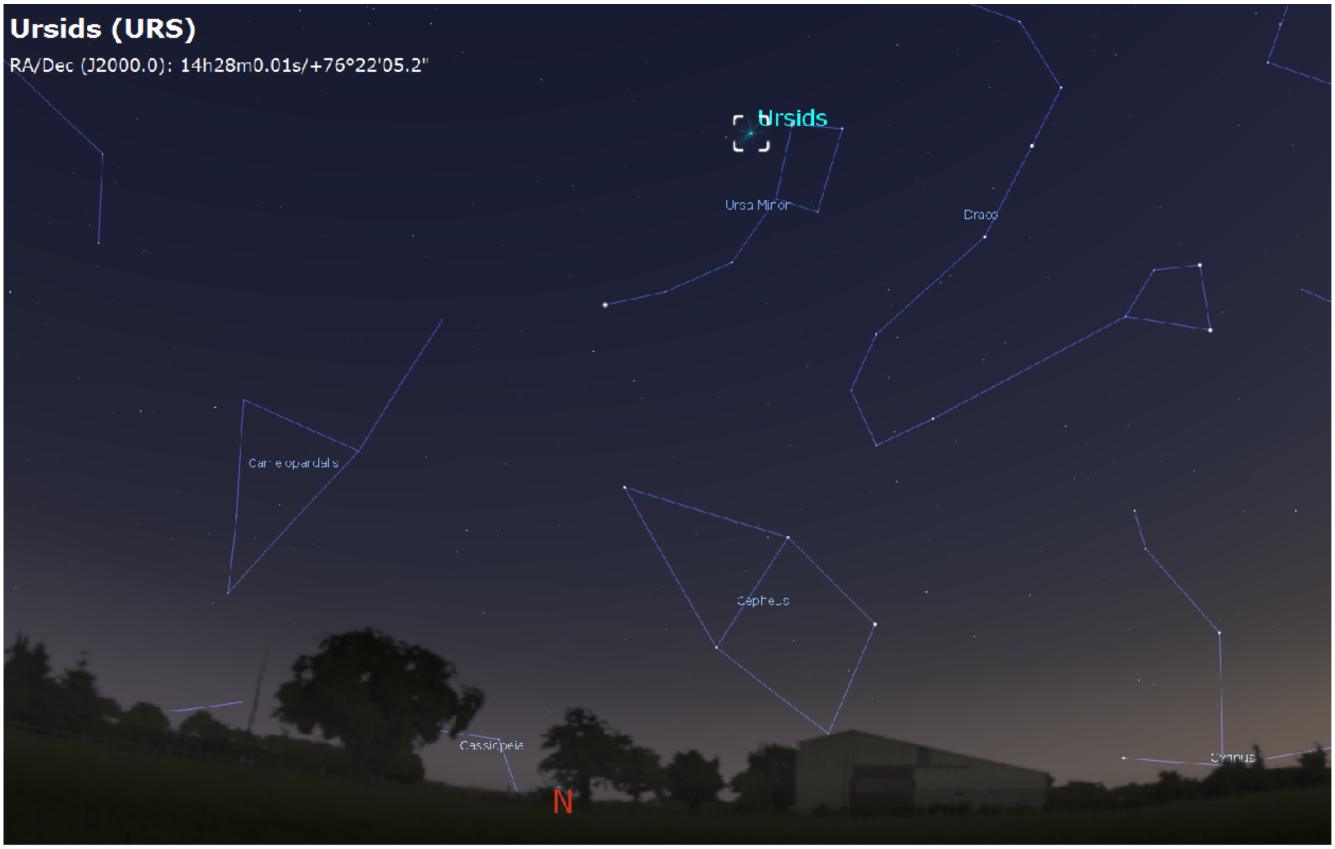
The International Space Station enters a period of full illumination throughout the length of its orbit, favoring the southern hemisphere with multiple visible passes. The period of full illumination begins on December 18th and ends on December 23rd. The International Space Station has an orbital inclination of 52 degrees relative to the equator, allowing for access from launching spaceports worldwide. This inclination also assures the the International Space Station reaches periods of full illumination biannually, on the weeks surrounding either equinox. NASA engineers call this 'high beta angle season,' a time when special precautions have to be taken aboard the station to avoid over-heating. @OzoneVibe on Twitter once suggested to us that such a season should be known as a FISSION, for Four/Five ISS Sightings In One Night.

Note that these orbital predictions are made the year previous... the orbit of the ISS evolves over time, as the station gets periodically boosted using the engines of visiting spacecraft to avoid reentry due to atmospheric drag. These predictions are most likely to be off by a day or so. Follow us on @Astroguyz for updates.

Routine spacewalks generally aren't undertaken by astronauts during periods of full illumination, to avoid the possibility of overheating. Likewise, the giant solar panels of the station are also feathered during this period to provide artificial shade.

The movie *Gravity* depicts travel between the Hubble Space Telescope, the International Space Station and the Chinese space station Tiangong-1, an impossibility as the three objects are in completely different orbits.

Friday, December 22nd: The Ursid Meteor Shower



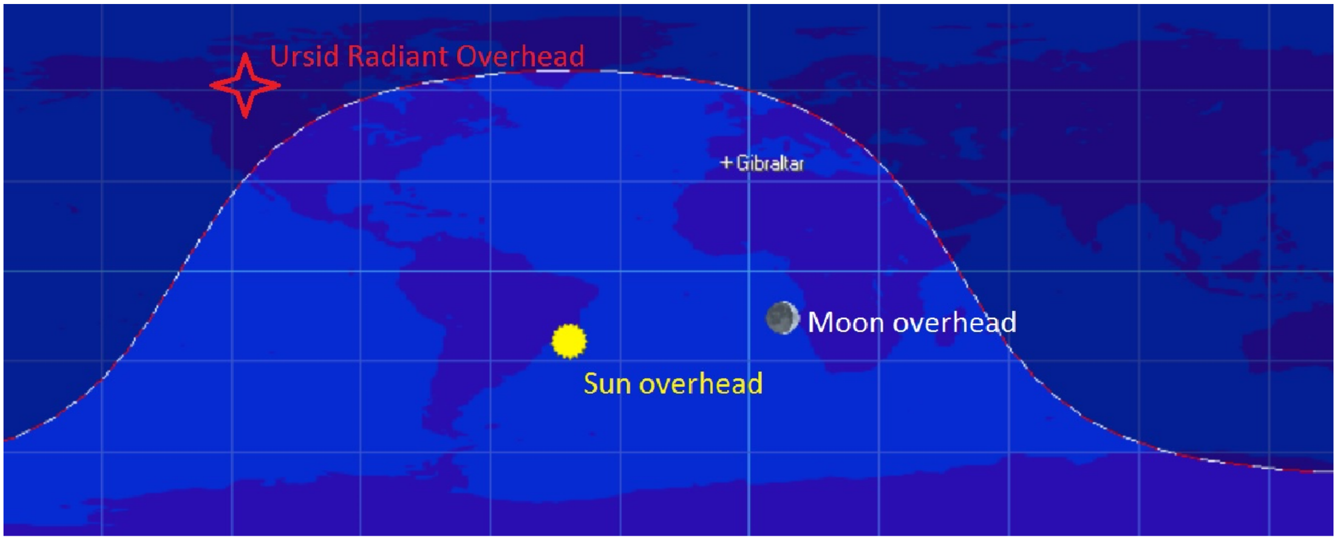
The Ursid meteor shower radiant on the morning of December 22nd. (Credit: Stellarium)

The Ursid meteors are expected to peak on December 22nd at 14:45 Universal Time (UT), favoring northwestern North America. The shower is active for a one week period from December 18th to December 25th, and can vary with a Zenithal Hourly Rate (ZHR) of 10-70 meteors per hour, to short outbursts briefly topping a hundred per hour, as last occurred 1945 and 1986. In 2017, the Ursids are expected to produce a maximum ideal ZHR of 20 meteors per hour. The radiant of the Ursids is located at right ascension 14 hours 28 minutes, declination 76 degrees north at the time of the peak, in the constellation of Ursa Minor (the Little Bear, sometimes referred to as the asterism of the Little Dipper).

The Moon is a 17% illuminated waxing crescent at the peak of the Ursids, making 2017 **a favorable year** for this shower.

The Ursid meteors strike the Earth at a moderate/fast velocity of 33 km/s, and produce a

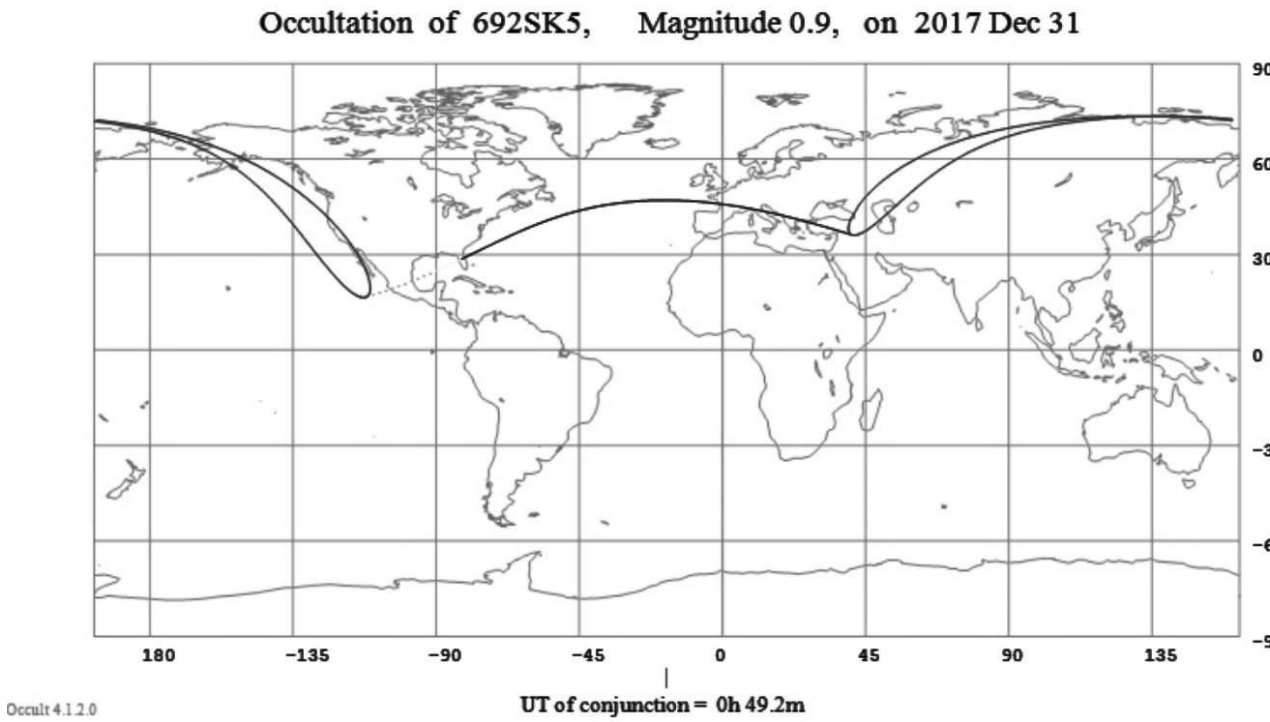
moderate number of fireballs with an r = 3. The source of the Ursid meteors is periodic comet 8P/Tuttle. Calculations carried out by meteor analyst Jérémie Vaubaillon suggests that the Earth may encounter an Ursid dust trail ejected from its parent comet in 884 AD.



The orientation of the radiant vs the Sun, Moon and Earth's shadow on December 22nd at 14:45 UT. Created using Orbitron.

A compact stream, the Ursids are one of those elusive showers that peak sharply in activity over a few hours, only to then once again fade to obscurity for another year.

Sunday, December 31st: The Moon occults Aldebaran



The occultation footprint for the December 31st event. Image credit Occult 4.2.

The 94% illuminated waxing gibbous Moon occults the +0.9 magnitude star Aldebaran. The Moon is 2 days past from Full during the event. Both are located 150 degrees east of the Sun at the time of the event. The central time of conjunction is 00:49 Universal Time (UT). The event occurs during the daylight hours over northern Mexico and the southwestern United States, and under darkness for northeastern North America and northern Europe, including the United Kingdom, New England and the Canadian Maritimes. The Moon will next occult Aldebaran on January 27th, 2018. This is occultation 39 in the current series of 49 running from January 29th, 2015 to September 23rd, 2018. This is the final occultation of a bright star by the Moon for 2017.

Post-occultation as seen from Mapleton, Maine. Image credit: Stellarium.

The maximum duration of an occultation of a star or planet by the Moon is 1 hour and 7 minutes.

Resource and Reference List

Compiling an extensive list of astronomical events for the coming year is an exercise in culling and pulling together resources from disparate corners of the web, planetarium programs and reference books. Here's what we're looking at for the coming year, and the sources of the info for 2017:

- Starry Night Pro planetarium software (star charts, comet paths, etc).
- Stellarium: A free planetarium application.
- Astropixels Fred Espenak.
- Fourmilab for Venus and Mercury elongations, Moon phases, and apogee/perigee.
- Mike Zeiler's Eclipse Maps website.
- NASA/GFSC Eclipse webpage, maintained by Fred Espenak.
- Seiichi Yoshida's *Weekly Information About Bright Comets.*
- Steve Preston's Top Occultation events for 2017.
- The International Occultation Timing Association (IOTA).
- U of Nebraska-Lincoln (double star sims).
- Comet Prospects for 2017 (The British Astronomical Association).
- Meteor Showers for 2017 (The International Meteor Organization).

And finally, a shout out to friends, space fans and readers of *Universe Today* who took time to cast eyeballs over these events and offered suggestions for this and previous years. On to 2018!

Appendix I - Calendar of Events

101 Astronomical Events for 2017
(Note: events in bold are the best of the year)

January

1-The solar cycle in 2017
3-Moon occults Mars

3-Quadrantids

4-Earth at perihelion

4-Io/Ganymede double shadow transit season one begins

9-Moon occults Aldebaran

12-Venus reaches greatest elongation

15-Moon occults Regulus

19-Mercury reaches greatest elongation

February

5-Moon occults Aldebaran

11-Penumbral lunar eclipse

11-Moon occults Regulus

11-**45P/Honda-Mrkos-Pajdusakova passes 0.08 AU from Earth**

26-Annular solar eclipse

March

1-Zodiacal light season

5-Moon occults Aldebaran (Best for North America)

10-Moon occults Regulus

15-Comet 2P Encke at its brightest

20-Northward Equinox

21-GEO satellite eclipse season

April

1-Moon occults Aldebaran

1-Mercury reaches greatest elongation

5-Comet 41P/Tuttle-Giacobini-Kresak at its brightest

7-Moon occults Regulus

7-Jupiter reaches opposition

22-Lyrids

22-Phi Puppids

28-Moon occults Aldebaran

May

4-Moon occults Regulus

4-407 Arachne occults a +6.5 magnitude star

6-Eta Aquarids

12-Io/Europa double shadow transit begins

15-Comet C/2015 ER61 PanSTARRS may reach +7th magnitude

18-Mercury reaches greatest elongation

26-Closest perigee Moon of 2017

28-Io/Ganymede double shadow transit season begins

31-Moon occults Regulus

June

7-The Daytime Arietids

8/9-MiniMoon for 2017

15-Saturn reaches opposition

15-Comet C/2015 V2 Johnson may reach +7th magnitude

21-Northward Solstice

22-ISS all night for the northern hemisphere

22-Moon occults Aldebaran

23-602 Marianna occults a +7.3 magnitude star

27-June Boötids

28-Moon occults Regulus

28-Mercury passes 0.8 degrees north of Mars

July

3-Earth at aphelion

10-Pluto reaches opposition

20-Moon occults Aldebaran

25-Moon occults Mercury

25-Moon occults Regulus

30-Mercury reaches greatest elongation

30-July Delta Aquarids

August

7-Partial lunar eclipse

12-Perseids

16-Moon occults Aldebaran

21-Total solar eclipse

21-A Black Moon

21-Moon occults Regulus

29-59 Elpis occults a +8 magnitude star

September

01-Zodiacal light season

05-Neptune reaches opposition

05-Mars passes 0.7 degrees North of Regulus

12-The Moon occults Aldebaran

12-Mercury reaches greatest elongation.

16-Mercury passes 3' north of Mars (The closest planet-planet pass of 2017)

18-Moon occults Venus (Best planetary occultation of 2017)

18-Moon occults Regulus

18-Moon occults Mars

18-Moon occults Mercury

20-Venus passes 0.5 degrees north of Regulus. (**The Closest Planet-Bright Star passage of 2017)**

22-Southward Equinox

23-GEO sat eclipse season

October

1-Saturn's rings at their widest

5-Venus passes 0.2 degrees north of Mars

9-Moon occults Aldebaran

12-NEO Asteroid 2012 TC4 passes 0.03x LD from the Earth

15-Moon occults Regulus (The best occultation of Regulus for North America)

18-Mercury passes 0.9 degrees south of Jupiter

19-Uranus reaches opposition

21-Orionids

November

6-Moon occults Aldebaran

11-Moon occults Regulus

13-Venus passes 0.3 degrees north of Jupiter

16-Asteroid 1798 Watts transits Jupiter

17-Leonids

21-Alpha Monocerotids

23-Mercury reaches greatest elongation

26-335 Roberta occults a +3.4 magnitude star for Australia (brightest star occulted by an asteroid in 2017)

30-Meteor outburst from Comet 46P/Wirtanen?

December

3-Moon occults Aldebaran

4-Super Moon for 2017

5-The most northerly Moon (+20.0) for 2017

8-Moon occults Regulus

14-Geminids

19 -Most southerly Moon (-18.8) for 2017

19-Asteroid 2886 Tinkaping transits Jupiter

19-Most distant apogee Moon of 2017

21- Southward Solstice

22-ISS all night season for the southern hemisphere

22-Ursids

31-Moon occults Aldebaran

About the Author

David A. Dickinson is a long-time amateur astronomer, retired U.S. Air Force enlisted veteran, and science fiction author. David began compiling the astronomical events for the coming year on his blog www.astroguyz.com in 2009, and moved the collection to *Universe Today* in 2014. He sold his house in Florida in 2015 and now travels the world and writes with his wife, Myscha.